ILLUMINATING ENGINEERING

JANUARY 1952

◆

In Two Sections — Section 1

Featuring

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and
Lighting Progress in 1950-1951

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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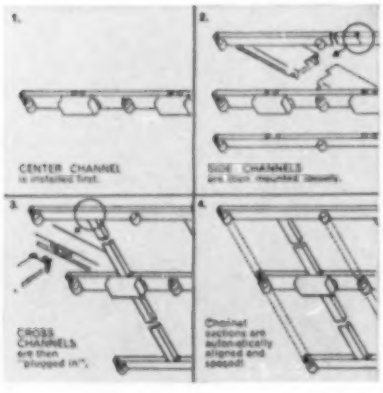

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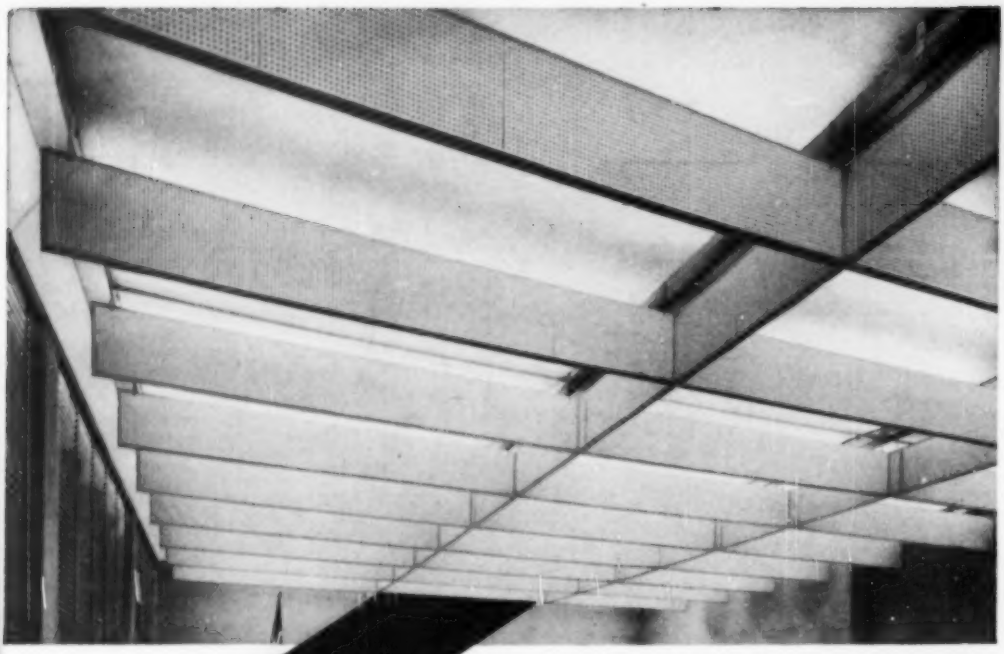

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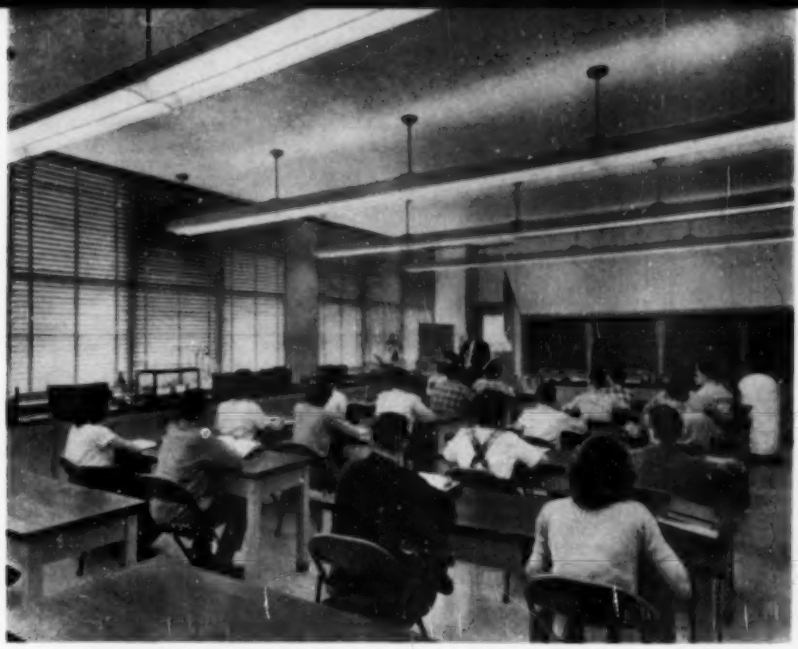


A School Lighting Survey Procedure

By LEONARD V. JAMES

There are two phases in this school lighting survey plan. The survey work sheets (in this article labeled Work Sheet A and B) are used in the field to record room details and readings of illumination levels and of brightnesses as they are observed; a four-page report (labeled Report Page 1, 2, 3, 4) is then filled in from this data including computed averages and ratios, to be presented to the architect and the school authorities. In this specific survey, applied by the author to the Naperville High School, readings were made under three conditions of illumination: (a) all daylight, (b) part daylight and half of the artificial illumination installation, and (c) all artificial illumination. The work sheets serve as a permanext record of conditions and readings at the time of the survey, and may be added to at any time with other lighting combinations or conditions.

SCHOOL lighting surveys are normally made for one or both of two reasons. One is to ascertain to what extent the results comply with certain accepted standards of illumination and brightness levels. The other is to provide a basis for comparing various lighting systems or installations.

This article presents the details of a survey which was made at the Naperville High School, Naperville, Illinois, in part for the two reasons given but primarily to inform the architect* and school authorities* as to the visual environment to be expected during normal school hours.

It was recognized that a survey procedure was needed which would provide approximately accurate results and still be a practical field method. Such a procedure had been developed and the purpose of this article is to describe it, with complete results as observed or computed in this case, so that others may use it in part or in whole, as they may desire. It is also hoped that ultimately an approved practical but complete and satisfactory field method may evolve and be more or less universally used.

*Architect, Thos. J. Higgins Associates of Chicago (Mr. Higgins is also Director of Building Survey for the Chicago Public Schools and a past president of the National Council on Schoolhouse Construction); Superintendent of Schools, Ralph E. Beebe; Principal, Robert Van Adestine; President of Board, Lester Schloerb (also Director of the Bureau of Pupil Welfare for the Chicago School Board).

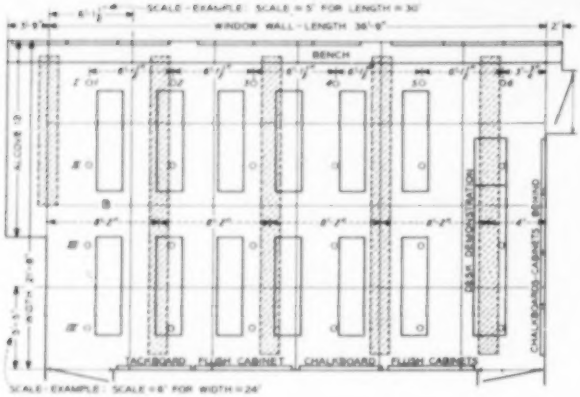
Author: Illuminating Engineering Consultant, La Grange, Illinois, Fellow I.E.S.

Three Investigations

Three complete investigations were made. The first (data given as Test (c) Work Sheet A) was at night, as part of an early study in February 1951. The objective was to ascertain artificial lighting possibilities for night-time use and for any very dark time of day which occasionally occurs in winter months in almost any local-

WORK SHEET A — Room Plan and Illumination Levels on Task Surfaces

School: Naperville High School, Naperville, Illinois; Room No. 305



Mark Plan (Suggested colors for use in field)

BLACK or BLUE

Dimension scale .....; dimension room .....
Locate with significant dimensions:
Windows .....; doors .....; chalkboards .....; tackboards .....; rows of desks .....; tables .....; closets .....; cases .....; charts .....; pianos .....; easel maps .....

GREEN

Locate luminaires .....; switches .....
Mark Ft-c stations small O .....; number rows and stations .....; mark luminaire and station spacings .....

RED—Mark rear seat observation station for brightnesses (B).

TEST (a) 5:00 - 5:00 PM 7/12/51 - All daylight

Footcandle Levels on Task Surfaces

Rows at Desk Level — Mark on Room Plan

	No	Stations at Desk Level Mark Stations on Room Plan 1	2	3	4	5	6	Chalk Board	Tack Board	
I	Three	117	73	115	89	100	98			
	Five	122	73	119	88	99	101			
	Readings	121	74	115	88	98	102			1
	Avg Ftc	120	73.5	116.3	88.5	99	101			
	Wdo²	650	660	650	650	650	650			
	Ftc.	120	76.5	116.3	88.5	99	101			
II	Three	42	39	43	44	44	45	35		
	Five	43	39	42	43	45	44	34		
	Readings	44	39	43	44	45	46	35		2
	Avg Ftc	43	39	42.7	43.7	44.7	45	34.7		
	Wdo²	625	620	620	625	630	650	620		
	Ftc.	44.7	40.9	44.8	45.5	46.1	45	36.4		
III	Three	26	26	25	25	26	24			
	Five	26	26	26	26	25	24			
	Readings	25	26	27	26	25	23			3
	Avg Ftc	25	26	26	25	25.3	23.7			
	Wdo²	640	650	655	670	680	640			
	Ftc.	29.6	26	25.8	26.6	24.8	26.3			
IV	Three	17	19	20.5	18.5	18	16	20	30	
	Five	18	19	20	19	17	16.5	19	30	
	Readings	18	19	21	19	18	16.5	18	31	4
	Avg Ftc	17.7	19	20.5	18.8	17.7	16.3	19	30.3	
	Wdo²	640	650	675	690	690	630	620	580	
	Ftc.	18	19	19.6	17.8	16.7	16.0	19.9	34	
	Avg	52.0	40.1	51.7	47.8	46.9	46.7	28.1	34	

Grand Average Footcandles = 46.8

TEST (b) 5:30 - 6:30 PM 7/12/51 - Part daylight, part artificial

Footcandle Levels on Task Surfaces

Rows at Desk Level — Mark on Room Plan

	No	Stations at Desk Level Mark Stations on Room Plan 1	2	3	4	5	6	Chalk Board	Tack Board	
I	Three	60	48	59	53	53	51			
	Five	62	46	57	51	54	52			
	Readings	61	47	58	52	53	51			1
	Avg Ftc	61	47	58	52	53.3	51.3			
	Wdo²	330	390	305	330	310	300			
	Ftc.									
II	Three	33	36	38	35	36	34	20	35	
	Five	31	35	36	37	37	35	21	37	
	Readings	32	35	37	36	36	34	20	36	2
	Avg Ftc	32	35.3	37	36	36.3	34.3	20.3	36	
	Wdo²	300	340	320	340	340	350	310	310	
	Ftc.									
III	Three	30	46	52	48	46	49			
	Five	30	47	51	49	48	50			
	Readings	30	46	50	48	47	49			3
	Avg Ftc	30	46.3	50.7	48.3	47	49.3			
	Wdo²	310	340	325	340	360	325			
	Ftc.									
IV	Three	24	47	45	44	44	38	22		
	Five	25	47	48	45	44	39	23		
	Readings	24	46	47	44	43	38	22		4
	Avg Ftc	24.3	46.7	46.7	44.3	43.7	38.3	22.3		
	Wdo²	300	330	325	350	360	320	320		
	Ftc.									
	Avg	36.0	43.0	48.1	45.2	45.1	43.3	21.3	36	

Grand Average Footcandles = 43.7

TEST (c) 5:45 - 6:00 PM 7/12/51 - All artificial

Footcandle Levels on Task Surfaces

Rows at Desk Level — Mark on Room Plan

	No	Stations at Desk Level Mark Stations on Room Plan 1	2	3	4	5	6	Chalk Board	Tack Board	
I	Three	39	47	48	43	43	44			
	Five	40	47	47	43	44	45			
	Readings	40	47	47	43	44	44			1
	Avg Ftc	39.7	47	47.3	43	43.7	44.3			
	Wdo²									
	Ftc.									
II	Three	51	55	60	52	51	50	23	19	
	Five	49	56	58	52	51	52	23	18	
	Readings	50	55	58	52	50	51	24	18	2
	Avg Ftc	50	55.3	58.7	52	50.7	51	23.3	18.3	
	Wdo²									
	Ftc.									
III	Three	57	53	55	52	51	54			
	Five	57	54	55	52	51	55			
	Readings	57	55	53	52	50	55			3
	Avg Ftc	57	54	54.3	52	50.7	54.7			
	Wdo²									
	Ftc.									
IV	Three	37	43	46	40	43	46	30	34	
	Five	36	44	45	43	41	47	32	33	
	Readings	36	43	48	42	43	47	33	33	4
	Avg Ftc	33.7	44	45.3	41.7	42.3	46.7	31.7	33.3	
	Wdo²									
	Ftc.									
	Avg	37.8	50.0	51.4	47.2	48.8	49.2	27.3	20.6	

Grand Average Footcandles = 47.0

Daylight Notes

If Daylight is involved —

1. Adjust daylight controls for greatest comfort. Report on Report Page 4.
2. Read Wdo² footcandles at window sill 45 degrees to glass, for each room observation.
3. Correct room observations by proportion for a mean value of Wdo², to reduce effect of daylight variations.

If a combination of daylight and artificial light is employed, and it is desired to correct for daylight variations, it will be necessary

4. Make all observations of lighting levels and of brightnesses at the same locations as is being done for daylight only.

(*Daylight Notes continued on Work Sheet B*)

◀ **WORK SHEET A**

for field and office, for footcandle readings. Wdo× is for daylight control readings, see text. A floor-plan diagram is provided on which room details are sketched and footcandle observation points located, with all dimensions.

REPORT PAGE 1 ▶

Title page for survey report, used also in the field to accumulate information.

SCHOOL LIGHTING SURVEY REPORT

NAPERVILLE HIGH SCHOOL
School

NAPERVILLE, ILLINOIS
Location

78
District

Supervision & Service

RALPH E. BEEBE
Superintendent

ROBERT VAN ADESTINE
Principal

FRED BROEKER
Custodian

Room Information

Room No. 305

WILLIAM HILL
Teacher

SOPHOMORE
Class

BIOLOGY LABORATORY
Subject

Design & Construction

THOS. J. HIGGINS ASSOCIATES
Architect

JOHN DOLIO
Engineer

Contractor

Electrical Contractor

Survey By

LEONARD V. JAMES
Director

LEONARD V. JAMES
Observer

WALTER A. MEARES
Recorder

ROY E. HOLLAND
Recorder

Dates

FEBRUARY 17, 1951

JULY 12, 1951

ity. Daytime tests were also made then but for various settings of the venetian blinds and for very poor daylight conditions.

So two additional daytime investigations (a) and (b), with a common adjustment of the blinds, were conducted on an afternoon and early evening in July and were planned to present results under very normal daytime conditions. The sky happened to be slightly overcast, shadows from the sun being dim, with the usual somewhat superior sky glow then available. A real advantage was the rather stable daylight existing under these sky conditions, facilitating the taking of data.

Survey (a), with daylight alone, was made in the late afternoon when the illumination levels at the far side of the room were still of the order of nearly 20 footcandles, to show distribution. The blinds had been lowered to leave a 20-inch vision strip and the slats closed to a 45-degree angle to avoid the high sky glare. This test was followed by a similar survey (b) a short time later when, without changing the blinds, the levels at the far side due to daylight had decreased to values under 10 footcandles and the inner half of the artificial lighting system was in use. Final results indicated that the vision strip itself permitted an objectionable sky brightness exposure for some of the pupils in these cases.

It was felt that a survey was not needed for normally superior daylight, so far as an analysis of pupil seeing conditions is concerned. The (a) investigation clearly indicated that the results would be very satisfactory at such a time, even with the sun and sky glare removed by the positioning of the venetian blind slats.

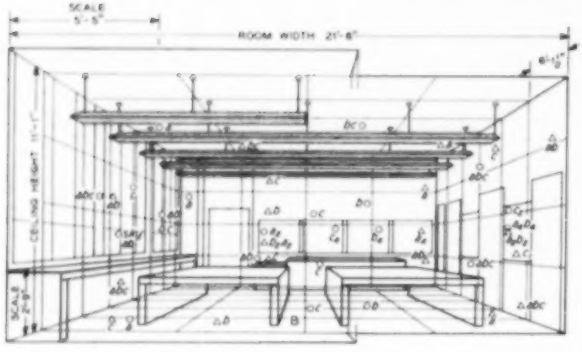
Condition of Lighting Facilities

The condition of the lighting facilities, both for daylight and for artificial light, was only somewhat better than average. The luminaires had been installed in the spring of 1950 and the lamps had been used normally during the intervening time, with few if any replacements. The fixtures and blinds had been washed at Christmas time, before the first survey was made in February. They had again been washed shortly before the July study. The slight room surface soil had not, of course, been removed.

The vertical position and the shape of the luminaire reflecting surfaces, however, are unfavorable to the accumulation of dust and favorable to natural cleaning by air flow. Also, the absence of louvers, made possible by the use of low brightness (40-watt T17) lamps in open top troffer type fixtures installed crosswise of the room, permits a considerable part of the light emitted from the lamps (from the "clean" under side of the lamps) to be delivered directly to the work, without interruption of any kind. Since the luminaires are so open and therefore easily cleaned (dusted or washed) and the housekeeping at the school is excellent, it is not probable that they will ever be permitted to become very soiled. Incidentally, the plain glass windows face southeast (in the test room) upon an open athletic field, with trees and other buildings far removed.

WORK SHEET B — Room Perspective and Brightness Levels in Visual Field

School: Naperville High School, Naperville, Illinois; Room No. 305



Reflectances (Avg Ft-L ÷ Avg Ft-c)*	At Task		Walls		Miscellaneous	
	Ft-L	Ft-c	Ft-L	Ft-c	Ft-L	Ft-c
	Tables		Upper Wall		Ceiling	
Three Ft-L & Ft-c Readings	4.4 4.4 4.5	81 79 80	26 26 27	32 32 32	67 66 66	84 84 85
Average	4.77	80	26.3	32	66.3	84.7
Reflectance	5.9 per cent		82 per cent		78 per cent	
	Chalkboard		Lower Wall		Trim	
Three Ft-L & Ft-c Readings	7.8 7.9 8.1	48 47 47	same as Upper Wall		17 17 18	46 44 49
Average	7.93	47.3			17.3	49
Reflectance	17 per cent		82 per cent		39 per cent	
	Tackboard		Window Covering		Floor	
Three Ft-L & Ft-c Readings	19.5 20 20	53 52 53	18 19 19	40 39 37	28 28 30	68 69 70
Average	19.7	52.7	18.7	38.7	28.7	69
Reflectance	37 per cent		48 per cent		42 per cent	

*Need not be taken at time of other tests.

Mark Drawing (Suggested colors for use in field)

BLACK or BLUE

Dimension scale _____; dimension room _____
Locate approximately:
Windows—Sill Height _____; Head Height _____; Doors _____;
Chalkboards: Top Height _____; Bottom Height _____;
Tackboards: Top Height _____; Bottom Height _____;
Desk Row Locations on Floor _____;
Luminaire Locations on Ceiling _____

GREEN: Locate Ft-c stations on chalk and tackboards by numbers.

RED: Indicate rear seat location for brightness observations by letter "B" on perspective.

NOTE: Observe brightness within 50° of view straight ahead, except as indicated. Mark brightness locations on perspective drawing, circles for maximum values, triangles for minimum values. For different locations at various times, indicate by subscripts.

TEST (a) 2:00 - 2:05 PM 7/ 12/ 51 - All daylight

Footlambert Brightness Levels on Surfaces in Visual Field
(Locate on Room Perspective)

	Front		Right Side		Left Side		Miscellaneous			
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	Chalkboard		Tackboard		On Blind or Shade		Ceiling		Luminaires 0-30°	
Three Ft-L & Ft-c Readings	Compute Ft-L from Footcandles Ft-c, vert sheet a, and Reflectances				100 Avg.	50 Avg.	73 72 68	21 19 18	Not Lighted	
Average					100	0	91	19.7		
Reflectance					510	560	460	495		
Ft-L	6.2	3.4	12.6	13.6	860	98	92	26		
	Above Board		Above Board		Above Window		Sky		Luminaires 30-45°	
Three Ft-L & Ft-c Readings	66 60 63	19 19 19	36 35 36	30 29 29	No Read		1500 1400 1400		Not Lighted	
Average	60	19	35.7	29.3			1430			
Reflectance	525	520	510	510			480			
Ft-L	24	24	65.5	37			1960			
	Below Board		Below Board		Below or Below Win.		Floor		Max. ratio Lum. Coil	
Three Ft-L & Ft-c Readings	17 16.5 16	5.8 5.6 5.6	40 41 38	20 18.5 19.5	17 17.5	5.3 5.0	10.7 10.5 10.3	9.1 6.0 6.3	Luminaires Not Lighted	
Average	16.5	5.67	40.7	19.3	17.2	5.3	10.5	5.9		
Reflectance	345	345	340	340	500	280	470	470		
Ft-L	40	9.8	92	45	19.5	5.9	14.5	8.2		

*Explain Ceiling Luminaire and sky observations on Page 4 of Report. Max. substitute luminaire brightness from Photometric report. Trim and Wall Brightnesses are in proportion to their reflectances.

**If Daylight is involved, follow daylight notes, on Work Sheet A in determining corrected footlambert values (Ft-L) from the average observed values and the Wdo² footcandles all observed simultaneously.

TEST (b) 9:30 - 9:35 PM 7/12/51 - Dark daylight, dark artificial

Footlambert Brightness Levels on Surfaces in Visual Field
(Locate on Room Perspective)

	Front		Right Side		Left Side		Miscellaneous			
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	Chalkboard		Tackboard		On Blind or Shade		Ceiling		Luminaires 0-30°	
Three Ft-L & Ft-c Readings	Compute Ft-L from Footcandles Ft-c, vert sheet a, and Reflectances				50 Avg. High Non-Low 100 Max 70 100	30 Avg.	68 70 68 68.3	13 14 13 13	Est. 13 From 10 Curve 10 350	10.9
Average						30				
Reflectance										
Ft-L	3.8	3.5	13.3	13.3	250	250	225	220	210	210
	Above Board		Above Board		Above Window		Sky		Luminaires 30-45°	
Three Ft-L & Ft-c Readings	23 24 22	17 18 17	37 39 37	16 15 16	No Read		950 850 800	180 200 450	Est. 12 From 13 Curve 14	
Average	23	17.3	37.7	15			900	390	450	12.9
Reflectance	175	170	250	250			220	220	210	210
Ft-L										
	Below Board		Below Board		Below or Below Win.		Floor		Max. ratio Lum. Coil	
Three Ft-L & Ft-c Readings	10 11 10	9 8 10	30 31 30	18 19 19	11 12 11	3 3.5 3	17 18 17	2.8 3.0 2.9	Approximately 350/15	203/60
Average	10.3	9	30.3	18.7	11.5	3.2	17.3	2.9		
Reflectance	270	270	250	250	220	230	220	220		
Ft-L										

TEST (c) 3:15 - 6:00 PM 2/17/51 - All artificial

Footlambert Brightness Levels on Surfaces in Visual Field
(Locate on Room Perspective)

	Front		Right Side		Left Side		Miscellaneous			
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	Chalkboard		Tackboard		On Blind or Shade		Ceiling		Luminaires 0-30°	
Three Ft-L & Ft-c Readings	Compute Ft-L from Footcandles Ft-c, vert sheet a, and Reflectances				25 24 25 24.7	8.1 7.9 8.0 8.0	60 58 60 58.7	17 16 16 16.3	Est. 17 From 15 Curve 16 150	16
Average										
Reflectance										
Ft-L	5.6	4.0	8.0	8.0						
	Above Board		Above Board		Above Window		Sky		Luminaires 30-45°	
Three Ft-L & Ft-c Readings	25 19.5 20	15 15 15	40 44 42	11.5 11.5 11.5	No Read		Night		Est. 16 From 17 Curve 17	
Average	20.2	15	42	11.5					650	16.7
Reflectance										
Ft-L										
	Below Board		Below Board		Below or Below Win.		Floor		Max. ratio Lum. Coil	
Three Ft-L & Ft-c Readings	10.5 10.5 11	8.6 8.7 8.8	24 25 25	10 10.5 10.5	18 17 16	5.9 5.8 5.7	18 17.5 18	10.5 10.5 11	Approximately 330/18	16/90
Average	10.7	8.8	25	10.3	16	5.8	17.9	10.7	90	.70
Reflectance										
Ft-L										

Daylight Notes (Continued from Work Sheet A)

5. Determine the portion of these values that is due to daylight only, by proportion from the daylight test data with the Wdo² values in the combination test.

6. Deduct this portion from the observed values in the combination test to obtain the portion due to artificial lighting alone.

7. Select a mean value of the Wdo² for the combination test observations and adjust the daylight portions of Ft-c and Ft-L for this mean value. Recombine these adjusted values with the artificial lighting portions to obtain total corrected values.

In general, it is much more informative in combination lighting tests to use observed values without reference to other tests. Wdo² readings would then provide incidental information only.

◄ WORK SHEET B

for field and office, for brightness and reflectance observations. A perspective diagram is provided on which additional room details are sketched and points are indicated at which brightnesses are measured.

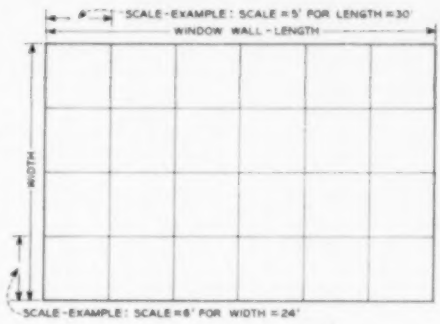
REPORT PAGE 2 ►

on which sketches and footcandle and footlambert locations are taken from work sheets. Diagrams are left blank here to show forms, adaptable to any room by inserting the scale values.

School Lighting Survey Report
Room Layout and Test Locations
Room Plan, Lighting Equipment and Footcandle Test Stations

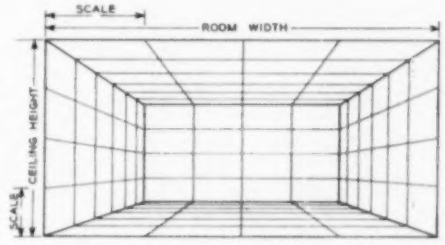
F is marked on Floor Plan
P is marked on Perspective
Room Details

Dimensions—F and P
Scale dimensions F and P
Approximate locations
Windows—length—F & P
Sill height .....
Head height .....
Chalkboard—length—F & P
Top height .....
Bottom height .....
Tackboard—length—F & P
Top height .....
Bottom height .....
Doors—F & P
Closets, Cases—F & P
Desk Rows, Tables—F & P
Easels, Maps, Charts etc.—F



Brightness Details (Mark in red)

"B" is rear center seat location of observer—F & P
Circles on perspective are maximum brightness of a surface—P
Triangles on perspective are minimum brightness of a surface—P
Subscripts on symbols indicate locations for different tests—F & P



Lighting Details
(Mark in green)

Lighting Equipment—F
Spacings—F
Switches—F

Fixture Stations
Number and Row—F
Spacings—F

Final Survey Results

The final survey results are given in the table (Report Page 3). It will be noted that the lighting in use is indicated in considerable detail (additional information given on Report Page 4). Also it will be seen that the illumination and brightness levels, plus the brightness ratios, are reported.

With reference to the footcandles, maximum, minimum and average values are indicated for the seeing tasks, on desks or tables, at the chalkboard and at the tackboard, and these are compared with the values recommended in the American Standard Practice. The condition of the lighting facilities is indicated in Sections B and C on Report Page 4. With this information, the architect and school authorities are in a position to appraise the results and to make such adjustments as appear needed.

The maximum, minimum and average task brightnesses at the desks or tables are computed by applying an assumed reading task reflectance of .75 to the corresponding footcandle observations. The extreme range of these values and of the footcandle values, under daylight conditions, is hardly fair, as the low levels near the inside wall definitely indicate a need for combination lighting at the time the test was made. The limited range (3 to 2) under artificial lighting would be expected with the type of installation used.

The ratios reported are suggestive of the quality of the brightness distribution but again are limited, as given, by using the *average* desk brightness as a base. The amount of variation in these ratios for pupils at various tables is determined by the varying illumination levels on those tables, a slight variation when artificial lighting is used.

The luminaire brightnesses, as taken from photometric test data, are compared with values given in the American Standard Practice. Values crosswise of the room (lengthwise of the rows of luminaires) are not included as the seating position in the room is fixed, toward the front. Approximately one lamp length, in one row, would be viewed by a pupil near the wall, within 30 degrees elevation, looking across the room. The lamp in this position would have about 700 footlamberts but would be in the less bright field of the luminaire reflectors and of the ceiling directly above. This unusual exposure condition was excused by the architect because of the maintenance advantage of the type of luminaire employed. Shielding of the lamps, crosswise of the luminaires, is in excess of 40 degrees.

A serious defect in the visual environment is disclosed in the use of black top laboratory tables. These introduce an objectionable ratio between the reading task brightness on the table and its immediate surrounds — less than one-fourth of the minimum permitted by the Standard Practice. This compares unfavorably with the ratio at the desks employed in the building, which is nearly double the minimum recommendation. It is understood that steps are being taken to correct this table top condition.

The levels of illumination at the chalk and tack boards do not fully comply with the Standard Practice, but the brightness ratios to the average desk task are satisfactory (not, however, to all task brightnesses). If these boards are to be used extensively, supplementary artificial lighting should be provided.

The high brightness of the low sky viewed through the vision strip em-

School: Naperville High School, Naperville, Illinois; Room No. 305

Illuminated Elements in Visual Environment

	Test (a)				Test (b)				Test (c)			
Date and Hour	3:00-5:00 PM 7/12/51				5:30-6:30 PM 7/12/51				5:15-6:00 PM 2/17/51			
Daylight in Use	All				All				None			
Artificial Light in Use	None				Inner half				All			
Daylight Conditions and Control Adjustments[1]	Generally fair. Bright sky. No sun in room. Blinds set 12° to 20° vision strip. Slats				Same as (a) except later. Sun lower, sky not so bright. Blinds same.				Dark outside Blinds closed			
Corrected for Mean Daylight Ft-c	650 Ft-c, 45° at Window				300 Ft-c, 45° at Window				No daylight			
Ft-c Levels at Tasks	Max.	Min.	Avg.	Rec.[2]	Max.	Min.	Avg.	Rec.[2]	Max.	Min.	Avg.	Rec.[2]
Desks or Tables	120	16.4	46.8	30	64	29[X]	43.7	30	58.7	39.7[X]	47	30
Chalkboards	36.4	19.9	28.1	30	22.3	20.3	21.3	30	31.7	23.3	27.5	30
Tackboard	34	34	34	30	36	36	36	30	23.3	18.3	20.8	30
Brightnesses in Ft-L[3]	Max.	Min.	Rel.[4]	Limit[5]	Max.	Min.	Rel.[4]	Limit[5]	Max.	Min.	Rel.[4]	Limit[5]
Avg. Desk Reading Task[6]	35.1		1.00		32.7		1.00		35.2		1.00	
Max. Desk Reading Task	90		2.56		48		1.47		44		1.25	
Min. Desk Reading Task		12.5	.36			21.7	.66			29.7	.84	
Desk Tops[7]	94	7.5	.60	.33	28.8	14.1	.60	.33	26.3	17.9	.60	.33
Table Tops[7]	6.6	.92	.073	.33	3.5	1.6	.073	.33	3.2	2.2	.073	.33
Front Wall				Between				Between				Between
Board (Chalk)	6.2	3.4	.096	10 and	3.8	3.5	.11	10 and	5.4	4.0	.11	10 and
Above Board	74	24	2.1	.10	23	17.3	.53	.10	20.2	13	.37	.10
Below Board	20	7.2	.20		10.3	9.0	.27		10.7	8.6	.24	
Right Wall				Between				Between				Between
Board (Tack)	12.6	12.6	.36	10 and	13.3	13.3	.40	10 and	8.6	6.8	.19	10 and
Above Board	45.5	37	1.3	.10	37.3	15.0	.46	.10	43	11.3	.32	.10
Below Board	52	25	1.48		30.3	18.7	.58		23	10.3	.29	
Left Wall				Between				Between				Between
Window Light Controls	640	58	18.2	10	100	30	3.1	10	24.7	8	.23	10 and
Above Windows	No Head			and	No Head			and	No Head			.10
Between Windows	19.3		.55	.10	11.3		.35	.10	36		1.03	
Below Windows		5.9	.17			3.2	.10			5.8	.17	
Ceiling	92	26	2.6	Between	68.3	13.3	.41	Between	58.3	16.3	.46	Between
Floor	14.5	8.2	.23	10 and	17.3	2.9	.09	10	17.7	10.7	.30	10 and
Trim	35	11.4	.32	.10	11	8.2	.25	and .10	9.6	6.2	.18	.10
Luminaire 0-30°				450	330		.73	450	330		.73	450
30-45°	Not Lighted			900	650		.72	900	650		.72	900
45-90°				2000	1100		.55	2000	1100		.55	2000
Lum. to Surface Beyond[8]	Not Lighted			20	330 to 15		22	20	330 to 11		30	20
Sky to Wall Adjacent[8]	1940 to 19.3		100	20	900 to 11.3		80	20	— to —			20
Max. Room Variation												
Sky to Chalkboard	1940 to 3.4		570	50*	900 to 3.5		260	50*	— to —			50*
Lum. (30°) to Board[8]	— to —		—	50*	330 to 3.5		94	50*	330 to 4		82	50*
To other surfaces	— to —		—	50*	330 to 1.6		205	50*	330 to 2.2		150	50*

* Disregarding Aisle Space

1. See Report Page 4 for further information.
2. Recommended by American Standard Practice for School Lighting (except 50 footcandles required for handicapped pupils and for sewing, typing and drafting).
3. Observed from central rear seat, (B) on drawings.
4. Relative to Average desk reading task — computed for either maximum or minimum having greater variance from the reference.
5. Limiting ratio or value, according to the American Standard Practice for School Lighting or at (*) to the National Council on Schoolhouse Construction.
6. For average footcandles condition, assuming 75 per cent reflectance on reading task.
7. This is same as ratio of reflectances of desk or table and task.
8. See page 4 for explanation, if considered needed.

◀ REPORT PAGE 3

showing pertinent final results in tabular form. See text for discussion and for explanation of several questionable values. Page is shown here, full scale, for greater legibility.

phasizes the need for controls at this point — either adjustable controls or better permanent, as in the use of other than clear glass.

Comments such as the above, with suggested corrections where needed, would be included with the report, in a separate recommendation. Incidentally, the number of points made should not be construed as indicating a poor seeing condition. Quite the reverse is true. All who have visited the school have pronounced the visual environment and controls to be of the best — the photograph scarcely does justice to the pleasing and comfortable effect. It just means that the survey is sufficiently thorough to locate even minor faults.

Field Observations

Work Sheets A and B, Test (a) give the field data as observed and computed, for the test involving daylight only. The three readings of footcandles or of footlamberts are averaged and this average is then corrected for a selected mean value of daylight footcandles as observed at the control meter on the window sill (see Fig. 3). The resulting corrected values of footcandles and footlamberts ($Ft\text{-}c_c$ and $Ft\text{-}L_c$) at the various stations are thus as noted. The need for this correction is merely to make it possible to compare the illumination levels and brightnesses in the various parts of the room, substantially as for a constant daylight condition — not from a precision standpoint.

The method of making the correction by direct proportion, for daylight conditions alone, is obvious and simple. When the interior lighting is from a combination of natural and artificial sources, this is only a little less simple but it may sometimes be misleading as explained later. From the daylighting test and by proportion to the later control readings, the interior illumination values for the daylight portion of the combination lighting may be determined. These can then be corrected for the selected mean value of the control meter for this test, the amount of the correction being added to or subtracted from the footcandle or footlambert observations as made, or the influence of the daylight and artificial light may be studied separately if desired.

The objection to the above plan for adjusting observed values under combination lighting, to compensate for varying daylight levels during the test (as explained in the final note on the form in Work Sheet A), is that brightness values must then be obtained at the same points in the two tests. They would not, therefore, necessarily show maximum and minimum values in each case. It is therefore recommended that this adjustment not be made but that actual maximum and minimum values of brightness be observed in the test with combination lighting, the daylight control readings being recorded as incidental information only. Since the footcandle readings are always observed at the same locations, these can be adjusted if desired.

The charts in Work Sheets A and B are drawn primarily to show the locations for the various observations. The room details are easily sketched on the blue-line printed forms which, by dimensioning ruled sections of the forms rather than making the drawings to a normal scale, can be adapted to virtually any room.

The information listed in Report Page 4 is self-explanatory except per-

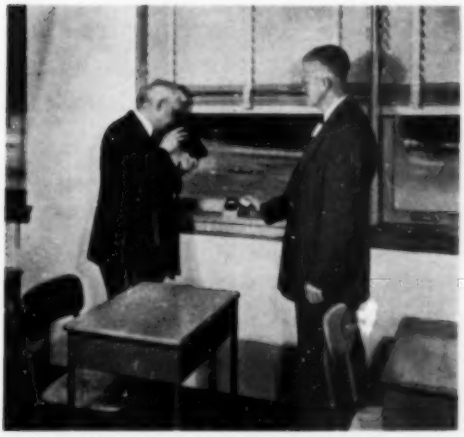


Figure 2. Light meter on a 45-degree easel at the sill indicates the variation in natural lighting during the test, readings being recorded as Wdo's. Walter A. Meares illuminating engineer of Chicago is assisting in the calibration of the light meter—a detail not required in the survey, but perhaps interesting to those conducting the investigation.

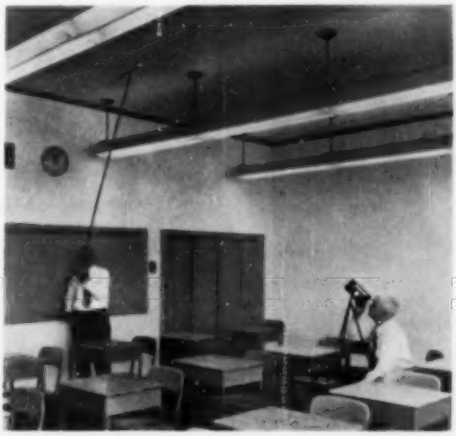


Figure 3. Measurement of footcandles and footlamberts at a surface from which to determine its reflectance. The magnesium disk is held against the ceiling by a special device described in the text and shown in Figure 4. Roy E. Holland, instructor in physics at the high school, is shown holding the target, the author observing.

School Lighting Survey Report

School NAPERVILLE HIGH SCHOOL, NAPERVILLE, ILLINOIS Room No. 305

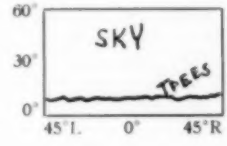
General Information

A—Structural: Material, color and per cent reflectance of

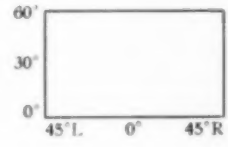
1. Ceiling	Acoustic Tile	Refl. .78	6. Furniture	Blond	Refl. .45
2. Walls	Plaster, not decorated	Refl. .82	7. Chalkboard	Green Composition	Refl. .17
3. Trim	Blond Birch	Refl. .39	8. Tackboard	Buff Composition	Refl. .37
4. Floor	Light tile, putty and green	Refl. .42	9. Window Covering (See B-1)		Refl. .48
5. Desks	Blond	Refl. .45	10. Tables	Dark Wood Tops (Lab.)	Refl. .055

B—Daylighting

1. Type and color of window light controls Blinds - light wood slats
2. Maintenance condition of controls and windows Good.
3. Adjustment of controls, each test All tests - blinds lowered to make 20° vision strip. Slats set at 45 degrees for Tests (a) and (b), closed for Test (c)



4. Condition of sky, each test (very clear, clear, hazy, cloudy, light overcast, heavy overcast) Slightly hazy for each test.
5. Explanation of sky brightness observations from indicated rear seat Through vision strip - could be eliminated by lowering blind to sill.
6. Sketch of outside view from window (for each test if much variation)



C—Artificial Lighting

1. Luminaires: Type Semi-direct, Model No. 1260, Shielding 40-7 Mfr. Light Mfg. Co., Susp. 25 inches, No. 18, Lamp Type F 40w T17 CW, Total No. of Lamps 36, Rated Lumens/Lamp 2300, Total watts (incl. ballasts) 1800, Area 860 Sq. Ft. w/sq. ft. 2.09, Avg. Ft-c 47.0 per w/sq. ft. 22.5
2. Maintenance condition of luminaires Good, recently cleaned
   Months since installed (a), (b) 13; (c) 8 Probable hours burned (a), (b) 1000; (c) 500
3. Switching arrangement Each crosswise row divided, inner half separately switched
4. Explanation of brightness ranges in room as needed (note 8, Report Page 3) Luminaire to darkest ceiling beyond. Sky brightness could have been eliminated (see B-5 above). Dark table tops (5.5 per cent reflectance) should be covered or replaced.
5. Luminaire information: curves, pictures, etc. attached

D—Operation of Survey

Measure room, mark locations for observations and sketch all details into Room Plan and Perspective. For daytime test, adjust window light controls for maximum comfort and locate light meter on sill near recorder. Use Work Sheets A and B (a, b, c) as needed, also Report Page 1 and 4 for field work. Check details required for Report Page 3. Complete Report Pages 1, 2, 3, 4 and add any desired material.

Attach additional pages as needed.

◀ REPORT PAGE 4

of the survey report, also used in the field for the accumulation of needed information. The diagram shows a sketch of the view from the window within the angles indicated.

haps that the sketch for B6 is an indication of what one sees at the various angles when looking out of the window—again for approximate comparison purposes for various rooms. This is repeated to provide for recording any marked changes—perhaps snow at one time only.

It will be noted that observations reported in Test (a) are repeated, for combination lighting, and also for artificial lighting only, in Tests (b) and (c). The tabular forms of Tests (b) and (c) may be used for subsequent tests by changing the subscript letters. In this way, the group of forms for illumination levels is kept separate from that for brightness observations and each can be continued indefinitely for as many conditions as desired.

With reference to the results for artificial lighting alone, it is only fair to note that the minimum footcandles shown were found in an aisle near the door in this odd shaped room (see floor plan, Work Sheet A). The levels at all working positions well exceeded that required by the American Standard Practice, despite the low watts per square foot employed (see Report Page 4).

The Survey Report

Since the architect and school authorities would be interested only in the final results, the report to them would include the title page (Report Page 1), one page containing both the floor plan and the perspective sketch with location indications for different tests identified by subscripts (Report Page 2), a third page containing the table of corrected results (Report Page 3), plus a fourth page containing the information given here in Report Page 4. Photographs and comments or recommendations are also included. To show the forms to better advantage, the details which would appear on the drawings in Report Page 2 are here shown only in Work Sheets A and B. These drawings which would be rough sketches were the material not being prepared for publication.

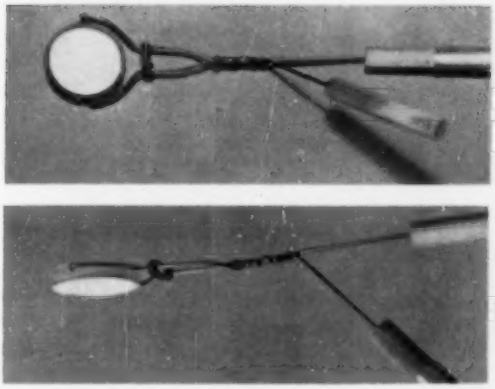


Figure 4. Close-up views of the holder for the magnesium target, shown in use in Figure 3 and described in the text. Sections of the pole are 15-inch lengths of aluminum thin-wall conduit, cut to fit a portfolio and connected by short pieces of ⅝-inch dowel.

Daylight Control Observations

Fig. 3 shows, not too clearly, the method of securing daylight control observations. A light meter is placed on a 45-degree easel on the sill, directed toward the sky, at a location near the recorder, and readings are made simultaneously with each interior observation. With a little patience when conditions are changing, plus alacrity during constant periods, remarkably little variation is encountered. Excessive variations may occur throughout the room when large cloud patches are moving across the sky—such days would merely be avoided.

The photograph in Fig. 3 shows the light meter being calibrated against a magnesium disk held in the same position—an unnecessary detail, as relative rather than specific results are used. Those making the test may, however, wish this information for general purposes.

More precise laboratory methods for recording these "control" values have been suggested. While excellent, no doubt, for laboratory purposes, there is a question whether even these methods can provide for an exact duplication of selected conditions *in the field*, or a precise comparison of conditions as found, while the method employed here is simple and practical and seems to give reasonably accurate results.

Observations as Reported

All observations of illumination as well as of brightness levels were, in this case, made with a brightness meter. Modern corrected light meters might have been employed for the footcandle readings at the desks and boards but the brightness meter would still be needed for the brightness readings. As previously noted, the luminaire brightnesses at various angles were taken from laboratory photometric test data which were available. The brightness meter was also used alone and with the magnesium disk to measure the footcandles and the footlamberts at any surface, from which to approximate its reflectance (Fig. 2). This is a simple method with sufficient accuracy for the need in field work.

The difficulty in placing the target against high wall or ceiling surfaces was solved by the fabrication of a holder (made from a coathanger), the prongs of which enter small holes drilled into the plastic case containing the magnesium. It is held by a pole assembled from 15" lengths of aluminum thin wall conduit (to fit a portfolio), joined together by pieces of ⅝" dowel. The device, alone and in use, is shown in Figures 2 and 4.

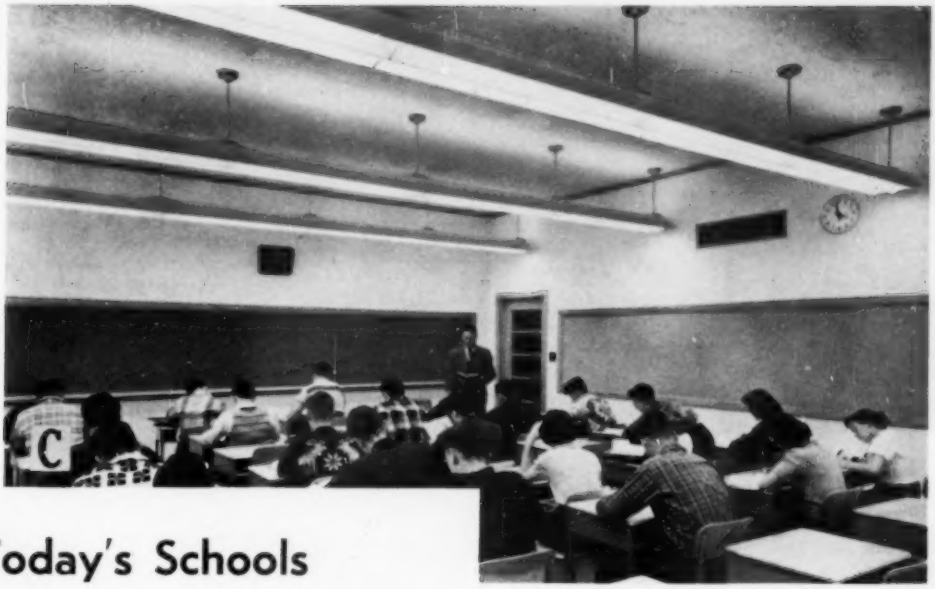
All photographs courtesy of Solar Light Manufacturing Company.

All over the country, school planners for both old and new buildings are providing students with visual environments in accord with I.E.S. school lighting recommendations — as to brightness ratios, shielding and illumination levels. While the installations shown in these pages by no means represent a symposium of all of the systems by which good quality lighting may be obtained in schools, they do indicate the trend in high level, low brightness, comfortable school lighting.

The Trend is to High Levels

Photo A (Above left) — Average maintained level of 30 ft-c in a grade school classroom. Note comfortable brightness ratios obtained with high reflectance surfaces. Walls are pale blue from point 5 ft above floor, lower wall light green. Chalkboard green, desks light maple; floor green and gray asphalt. Three 28-ft rows of units on 18-inch hangers; each row containing 14 48-inch T-12 lamps.

Photo B (Above) — Six rows of recessed luminaires, each 12 ft long using two 40W lamps per section, provide 50 ft-c on desk area; 25 ft-c vertical on chalkboard. Surfaces are 60% RF, green ceramic glass chalkboards, and mottled green and brown floors (45% RF).



in Today's Schools

Photo C (Above) — Suspended troffer type luminaire using low brightness lamps in high school classroom. Level on desks is 60 ft-c average; chalkboards 35, tackboard 38 ft-c. High reflectance room finishes provide comfortable visual environment.

Photo D (Left) — High school library with 60 ft-c horizontal on desks, 50 ft-c vertical on stacks. Lighting is from eight panel units on 19′ x 25′ centers. Each unit consists of 4′ x 8′ sections designed to be fastened together to make one large unit. Lamping is with 96″ T-12 lamps operated at 430 ma. The units are open at the top for ceiling illumination and are shielded with 45° cut-off fibre board louvers. In maintenance louvers may be discarded and new ones installed.

Photo E (Right) — Uniform illumination in high school sewing room. I.E.S. standard measurement showed 77 footcandles average. The intentions of the design were to maintain an average of 50 ft-c with semi-annual maintenance and a perimeter lighting of the room for evening adult education.

Photographs on these pages are:

A—Laidlaw Grade School, Western Springs, Ill.
B—Nausauket School, Warwich, R. I.
C—Naperville H. S., Illinois.
D—Argo Community H. S., Summit, Ill.
E—Downers Grove Community H. S., Illinois.
F—Argo Community H. S., Summit, Ill.
G—Reavis High School, Stickney, Ill.
H—Lincoln School, Mt. Prospect, Ill.

Photos and data supplied by Public Service of Northern Illinois, L. V. James, Gunther Lansen.

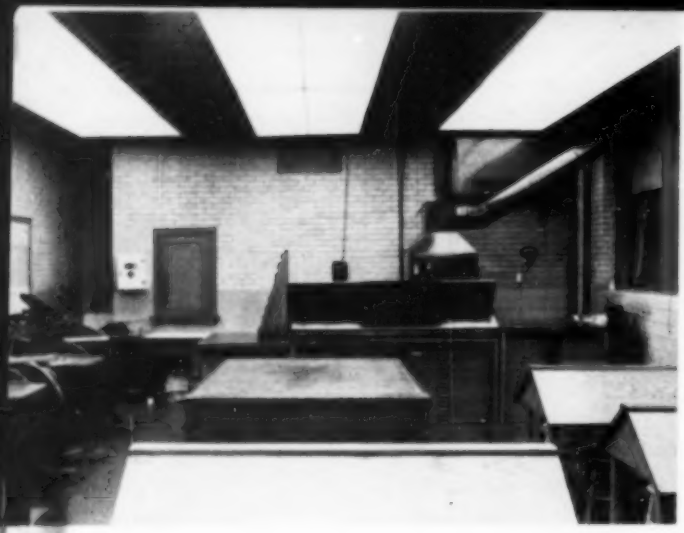


Photo F — Print shop using three 32-ft rows of panel units with solid corrugated plastic panels, reflectors over top. Average maintained illumination at work level is 100 ft-c. Each 32-ft row consists of four 4′ x 8′ sections; each section using four 96″ T-12 lamps operated at 430 ma. Sections are hinged for maintenance.

Photo G — A gymnasium lighted to 30 ft-c level. Recessed semi-flush lens boxes are on approximate 12′ x 12′ spacing; four rows of seven units per row over play area; one row of seven units over south balcony. Each box is equipped with four 200-watt PS32 inside frost lamps. Relamping is from the attic. North and east balconies are lighted with continuous row of single lamp louvered slimline strip. Surfaces are light, of the order of 70% RF.

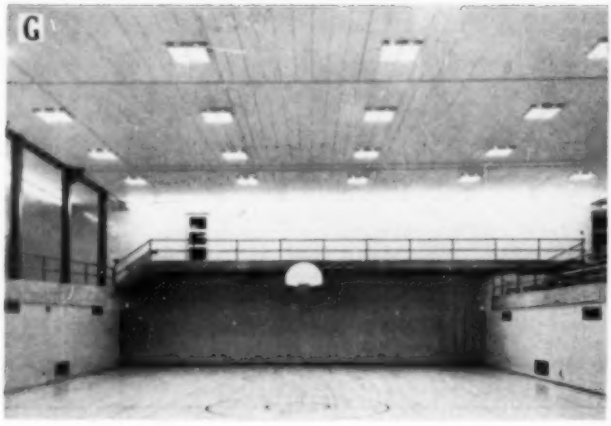
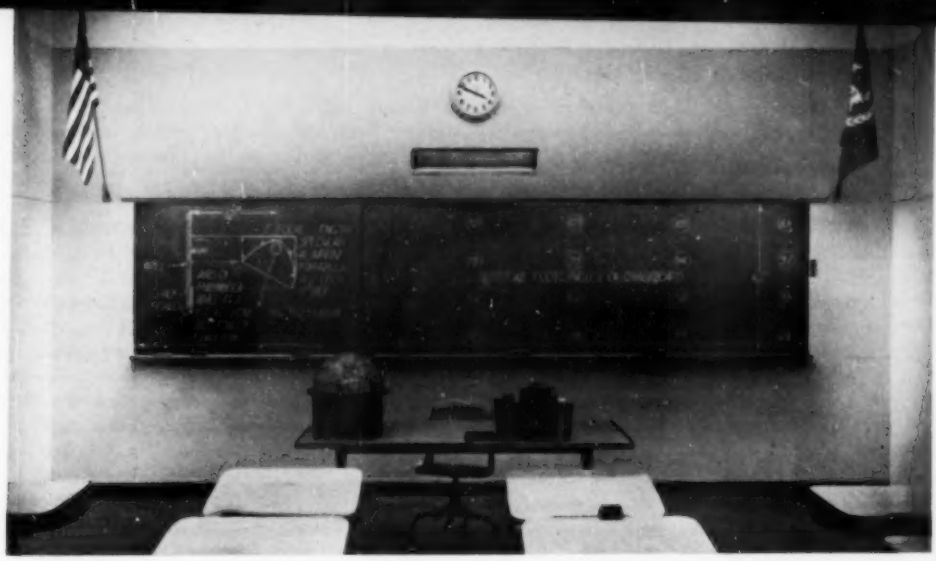


Photo H — Recessed fluorescent lighting in this classroom consists of two-lamp low-brightness troffers on seven-foot centers, running the width of the room horizontally. Illumination levels are of the order of 50 footcandles. Note the low brightness ratios obtained with this level, through the use of high reflectance surfaces on walls, desks and floors.



A Suggested Design for Chalkboard Lighting

By C. J. ALLEN

THERE have been tremendous improvements made in classroom illumination throughout the country. Little attention, however, has been given to the need for adequate illumination on the classroom chalkboards. The American Standard Practice for School Lighting calls for a minimum of 30 footcandles on the chalkboard and stresses the point that more is desirable where the teachers use the chalkboard extensively in their teaching procedure. With a typical good quality general lighting system of 30 footcandles the illumination on the board is roughly one-half that on the desks, or about 15 footcandles. It is recognized that enclosing globes of the general diffusing type and bare fluorescent lamps inherently deliver more light to the chalkboard, but they are not recommended as they also deliver an uncomfortable amount of light into the eyes of the students.

Chalkboard writing frequently combines adversely the principal factors which contribute to low visibility: small detail, low contrast, distance and sub-normal vision. Thus, it is not uncommon for a student seated at the rear of a classroom to be guessing much of the time as to what the instructor is putting on the board. As the classrooms become larger and the details on the board smaller, as in the case of technical subjects in high schools and colleges, this condition becomes critical.

Author: General Electric Company, Nela Park, Cleveland, Ohio.

Incandescent chalkboard lighting equipment has been available to improve the lighting on chalkboards, but no fluorescent fixture has been specifically designed for this purpose. To produce a significant improvement in chalkboard visibility it was considered desirable to design an experimental fluorescent unit which would add at least 50 footcandles over the board. This was accomplished with the unit shown in the illustration. Over the principal writing area of the board the illumination, with the addition of typical room lighting, is of the order of 100 footcandles. The apparent uniformity is surprisingly good even though a 3.5 to 1 variation can be measured from top to bottom of the board when there is no other illumination on the board. The operating cost is low as only 175 watts is involved. Maintenance should be minimum as the reflecting surfaces are facing downward in a position to collect little dust or dirt. The tubes are shielded to 60 degrees from the classroom side thus there is no brightness annoyance even to someone standing close to the board. As the light comes from two directions there is no shadow of the hand as one writes on the chalkboard. The lamp and reflector are so arranged that the direct rays of the lamp illuminate the top of the board and the maximum output of the reflector is directed to the bottom of the board. The size of the specular aluminum parabolic reflector is such as to amplify the

bare lamp candlepower by about five times in the direction of the axis of the parabola. The unit is inconspicuous as the front face is painted the same color as the wall behind it.

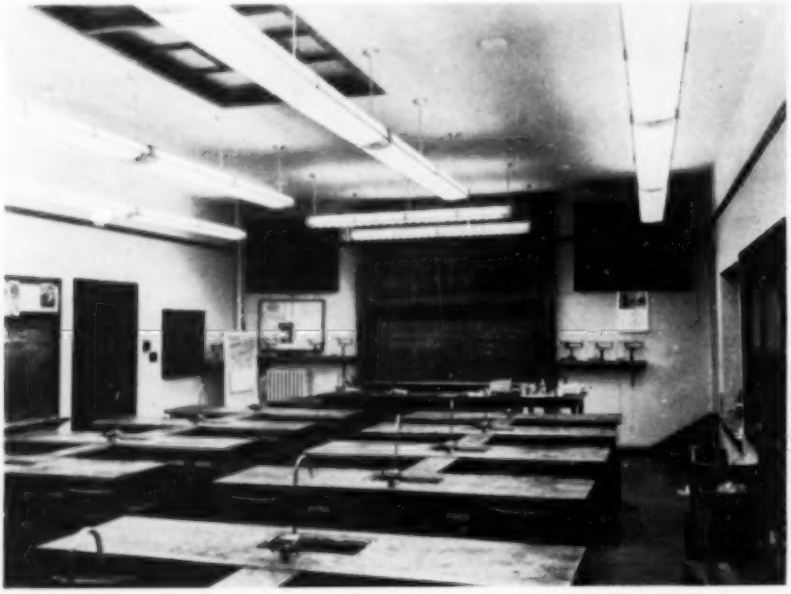
Green chalkboards have become very popular in schools. The reason has been that they provide a more pleasing color appearance and blend in brightness-wise with the wall surrounding them. With a 17 per cent reflectance green chalkboard and a 50 per cent reflectance wall the practical goal of a 3 to 1 brightness ratio is achieved when equal illumination is on both. A natural slate chalkboard of 8 per cent reflectance offers better contrast with the white chalk and thus theoretically better visibility. However, its brightness ratio with a 50 per cent reflectance wall is 6 to 1. Where a slate chalkboard is used with a chalkboard lighting unit, such as described, so that it has 100 footcandles on it, its brightness is about 8 footlamberts (100 ft-c x .08 reflectance). If the room lights provide 15 footcandles on an adjacent 50 per cent reflectance wall, the wall brightness is roughly 7.5 footlamberts. Thus, under this condition the slate chalkboard and the adjacent wall can have a 1:1 brightness ratio which is considered ideal.

While this unit was designed for chalkboard lighting purposes, it is obvious that it fulfills the need of other applications. Among these would be the lighting of bulletin boards, murals, and any area where vertical surfaces need to be lighted.

Standardization for Lamp Replacement

The Community High School in Downers Grove, Ill., has settled on T-12 96-inch 75-watt lamps for standardization in replacement. In the relighting of the Chemistry Laboratory (shown in photograph) and the adjacent Physics Laboratory, four rows of two-lamp luminaires suspended 25 inches from the ceiling, were suggested by the center skylight. The two center rows are broken at one end and run cross-wise over the teaching area. This arrangement seems desirable and is being considered in plans for future relighting of other classrooms in the school.

An average of 62 footcandles at desk level is achieved over the room, which is 22′ 11″ x 40′ 7″ with ceiling height of 11′ 6″. The ceiling is flat white, side walls 55 per cent cream. Wall charts cover one wall and cabinets and chalkboards are on others. Photo courtesy The F. W. Wakefield Brass Company.



Grid-Systems For Classroom Lighting

By BENJAMIN SCOTT BENSON, JR.
ERIC H. CHURCH

EVER SINCE public acceptance of the fluorescent lamp as a practical source of light, illuminating engineers have been trying to devise methods of minimizing the considerable numbers of luminaires which have been necessary to provide desired illumination levels. Among these methods are, notably, louvered ceiling systems, translucent panels and troffers. Recently interest has developed in still another method which shall be referred to in this article as a "grid-system."

The grid-system has been available to the public for some time on a custom-made basis. It is only now, however, that such a system is being made available as a production item by various manufacturers.

Broadly speaking, the grid-system can be classed as an "over-all type" consisting of a skeletal framework mounted to the ceiling, providing for the support and proper spacing of a series of fluorescent lamps and intervening shields.

Because of the interest evidenced in these systems the authors have investigated the use of this type of lighting in two similar classrooms in a grade school.*

The grid-systems under consideration mounted 96-inch, T-12 fluorescent lamps on 24-inch centers. The shields, mounted midway between the lamps, did not extend to the ceiling for purposes of efficiency and economy although they provided an effective crosswise lamp shielding of 45 degrees (Fig. 1).

The system for each room was formed of a series of 4-lamp sections, each consisting of two 2-lamp rows. When assembled on the ceiling, the overall system width was slightly over 16 feet with the length in multiples of four feet. Shown in Fig. 2 is the reflected ceiling plan of a typical room giving the arrangement of a grid-system using a total of 28 lamps. It should be noted that there is no shielding between the end lamps and their adjacent walls. Shields at these locations would serve no useful purpose and would, in fact, reduce desirable end-wall illumination.

The grid-systems in both schoolrooms are offset 12 inches from the room centerline and away from the window wall in order to increase the illumination on the inside rows of desks which are least able to take advantage of natural lighting during the regular school day. Electrical circuits are so arranged that the inner half of the system can be operated separately when desired.

By using both classrooms and their grid-systems, it was possible to investigate the effects of several variables upon the lighted environment. These included lamp operation at both 425 and 200 milliamperes, the use of systems incorporating 28 lamps and, again, 24 lamps (a multiple of the basic 4-lamp section) and the use of both translucent and opaque shields.

The translucent shields consist of narrow steel frames containing lengths of white polystyrene plastic which both diffusely transmit and reflect light from the lamps. Narrow convex ribs running the length of the shield serve to break up the specular portion of what would ordinarily be a mixed

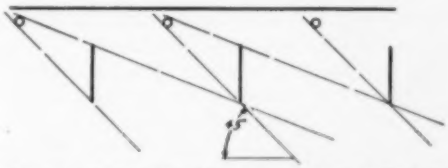


Figure 1. Cross-section view of grid-system showing 45-degree lamp shielding.

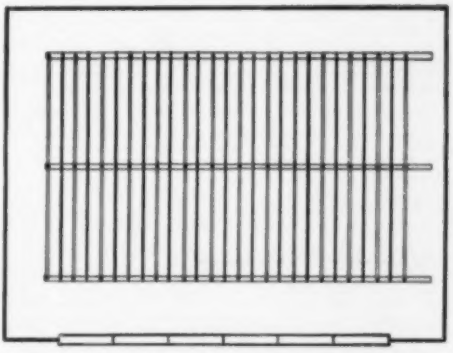


Figure 2. Reflected ceiling plan of classroom showing a 28-lamp grid-system.

*Central School, Mount Prospect, Illinois.
Authors: Benjamin Electric Manufacturing Company, Des Plaines, Illinois.

first-surface reflection. The combined reflectance and transmittance of the plastic is over 97 per cent.

The opaque louvers consisted of two sheets of white finished perforated acoustical material mounted back-to-back and supported in the same framework as for the plastic. The measured reflectance of the white surface (including the perforations) was found to be 76 per cent.

The two rooms were practically identical in every respect including dimensions and finishes. Both had three painted walls and one papered wall whose predominant background closely matched the reflectance of the other three. In one room the papered wall was at the front while in the other it was at the back. Pertinent room data are:

Room length	32'0"
Room width	24'8"
Ceiling height	11'11"
Reflectances	
Ceiling	81%
Walls	59%
Blackboard	6%
Floor — Gray tile	21%
Black tile	6%
Window shades	45%
Desks	45%

Horizontal footcandles were measured at a total of 64 uniformly spaced stations for each grid-system investigated. Illumination measurements were taken with a cosine- and color-corrected footcandle meter calibrated over the range of values encountered. Brightnesses were measured with a calibrated Luckiesh-Taylor brightness meter by an observer seated at the last desk in the second row from the left. All readings were taken at night. A recording voltmeter measured the voltage for every reading. Illumination data were determined as shown in Table I.

Figure 3. Typical room using six 300-watt indirect luminaires. (Brightnesses in footlamberts marked on photo.)

Assuming a maintenance factor of 70 per cent and the lamp manufacturer's lumen ratings for standard warm and standard cool white fluorescent lamps, data were calculated as in Table II.

Each of the rooms in this investigation was originally equipped with six 300-watt incandescent indirect luminaires. Fig. 3 illustrates the general lighted appearance of one of the rooms before being redecorated to the reflectances previously mentioned. Marked on the photograph are measured brightnesses in footlamberts. The average measured illumination (as found) was 6.2 footcandles.

Fig. 4 shows the measured brightnesses (at 100 hours) in the same room after redecorating and using a 28-lamp, translucent shield grid-system operating at 200 milliamperes. Unfortunately, the redecorating program did not include lighter colored chalkboards and floor coverings. These would have added materially to the pleasing appearance of the overall lighted environment.

TABLE I.

Quantity of Lamps	Lamp Current in Milliamperes	Type of Shield	Lamp Color	Average Measured Footcandles*
24	200	Translucent	Standard Warm White	50.2
28	200	Translucent	Standard Warm White	57.8
28	200	Opaque	Standard Warm White	52.8
28	425	Translucent	Standard Warm White	99.4

*At 100 hours of burning

TABLE II.

Quantity of Lamps	Lamp Current in Milliamperes	Type of Shield	Calculated Average Maintained Ft-c (M.F. = 70%)		Coefficient of Utilization
			Standard Warm White Lamps	Standard Cool White Lamps	
24	200	Translucent	35.2	33.6	.56
28	200	Translucent	40.4	38.0	.55
28	200	Opaque	37.0	34.7	.50
24	425	Translucent	60.6	56.9	.57
28	425	Translucent	69.6	65.4	.57

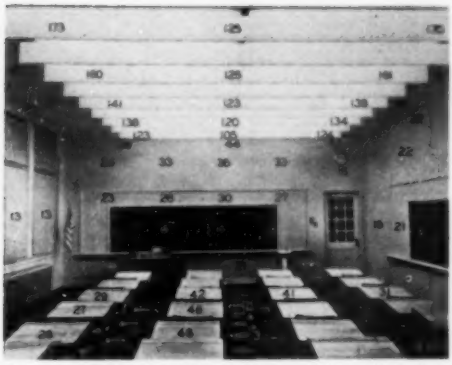


Figure 4. Same room redecorated and with grid-system. 28 lamps at 200 mils. Translucent shields. (Brightnesses in footlamberts marked on photo.)

Fig. 5 shows the same installation as in Fig. 4, except using a 24-lamp, translucent shield grid-system. The removal of a basic 4-lamp section places the first row of lamps two feet farther away from the wall with a resultant change in front-wall brightnesses as shown.

Fig. 6 shows a 28-lamp system using the opaque shields, and, again, with the lamps operating at 200 milliamperes. Brightness readings on the front wall were measured on the light background of the wallpaper.

Fig. 7 shows a 28-lamp system using the translucent shields with the lamps operating at 425 milliamperes instead of 200 as in Fig. 4. Brightnesses were found to be generally higher throughout the room.

Because the shields stop short of the ceiling, it is possible for an observer to look between the louvers and see narrow strips of the ceiling at angles less than the 45° shielding for the lamp. In certain instances a visible ceiling strip may be located directly above a lamp row where its brightness may be increased to a certain extent. The brightnesses of these strips have proved not objectionable as the strips are narrow (subtending a vertical angle at the eye of considerably less than one degree) and are bounded by the intermediate brightnesses of the adjacent shields. Brightness measurements of these strips with the lamps operating at 200 milliamperes were found to vary between 314 and 342 footlamberts. At 425 milliamperes to the lamps the measured brightnesses ranged between 479 and 668 footlamberts.

In view of the results obtained, it would appear that such a grid-system can be suitable for installation in school classrooms above the kindergarten level as well as in other locations where orientation

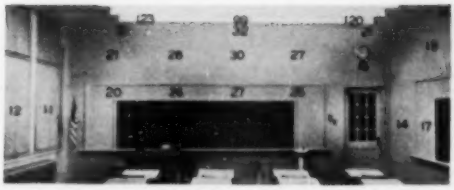


Figure 5. Same room. 24 lamps at 200 mils. Translucent shields. Brightnesses in footlamberts marked on photo.)

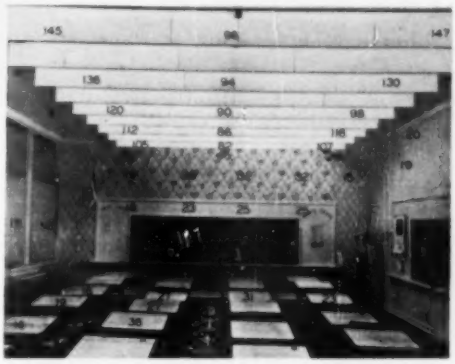


Figure 6. Same room. 24 lamps at 200 mils. Opaque shields. (Brightnesses in footlamberts marked on photo.)

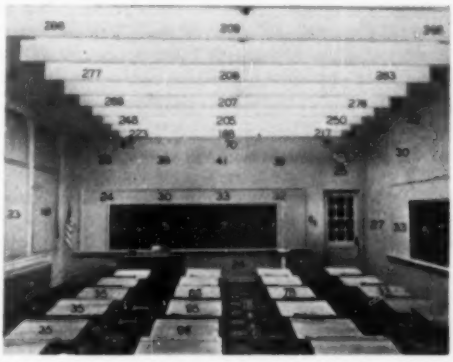


Figure 7. Same room. 28 lamps at 425 mils. Translucent shields. (Brightnesses in footlamberts marked on photo.)

of the observer can be such as to take advantage of the maximum shielding offered. For classroom lighting it is recommended by the authors that the lamps operate at 200 milliamperes for lowered brightnesses in the 0 to 45 degree zone and that the room interiors be finished according to the American Standard Practice for School Lighting.*

*American Standard Practice for School Lighting. Approved September 20, 1948. American Standards Association, Inc., A.I.A. 31-F-28, A23.1—1948 UDC 628.9; 727.1.

Classroom Designed for Light and Sound Control

By WILLIAM FOULKS
GEORGE GILLEARD
WILLIAM WEIBEL

Describing a lighting system designed to provide both light and sound control for an interior. Packaged, pre-wired sections are extended and joined upon installation to support continuous lines of light. Acoustical baffles shield the light and absorb sound.

THE ADVANTAGES of better lighting and of acoustical treatment for interiors have been known and individually applied for some time. It was logical therefore that the desirable features of light and sound control be incorporated in one system, for maximum benefit in design, installation and operation.

The long fluorescent lamps suggested a system which could be factory-wired in sections and completely packaged. For installation, sections would be extended and lamps mounted like ladder rungs between and at right angles to the channels carrying the control equipment. This arrangement of lamps and channels could be developed as a practical lighting system, one which would appear as an integral part of the completed room. Such a system was developed and a schoolroom test installation made in December 1949,[1] in which lines of 96-inch T-12 fluorescent lamps were mounted close against the ceiling, with 10-inch wide baffles hung between the rows. In that installation, 55 footcandles of illumination was furnished at comfortably low brightnesses.

With the use of acoustical material for the baffles, sound control has been introduced in subsequent installations. A typical example of this system is shown in Figs. 1 and 2, showing a classroom at the Hinsdale (Illinois) Township High School. The room is 26 feet wide, 35 feet long and 11 feet high. The area on the ceiling, covered by the light and sound control system measures 24 feet by 28 feet and uses 36 T-12, 96-inch lamps. Nine rows of acoustical panels crosswise of the room, and two rows lengthwise, shield the lamps, and at the same time furnish sound control within the area.

Average illumination at desk level after 100 hours of lamp life was 53 footcandles. This initial value may be expected to result in an average maintained level of 40 footcandles if allowance is made for 25 per cent depreciation due to aging of lamps and collection of dust and dirt on the room surfaces. The maintenance features of this system, incidentally, commend themselves to those interested in costs of operation, since there are no horizontal surfaces to collect dust except the tops of the lamps, which are easily cleaned. The maintained vertical illumination along the center line of the chalkboard will vary from 25 footcandles near the bottom to 35 footcandles at the top. The position of the lamps and baffles with respect to the board is such that no annoying reflections occur.

Brightness values shown on the photograph are as measured after 100 hours of lamp operation and do not include a factor for depreciation. Footcandle values, as mentioned, include a factor of 25 per cent for depreciation after the first 100 hours.

In this particular room, reflection factors range from 85 per cent on the white ceiling, to 10 per cent for the black chalkboard. The acoustical panels are 75 per cent; side wall of light green is 65 per cent; end walls of light green, 60; venetian blinds closed, 60; desk tops of blond wood, 40 per cent; green floor, 20 per cent.

The total watts in this installation, including ballasts, is approximately 2000, or 2.2 watts per square foot. The system, under the conditions in this room, is therefore providing more than 18 footcandles maintained average illumination for each watt per square foot.

Construction and Packaging

For the system described, factory-wired sections may be disjointed and folded for packaging. A typical folded section is packaged in a carton 6" x 15" x 96". This section, when extended, covers a ceiling area 8 feet by 16 feet, several sections being required for a classroom, the number and size of which will depend upon the room size and proportions. Such sections may be mounted end-to-end and side-by-side. Baffles for light and sound control are supported from the channels and are parallel to the lamps.

Authors: Curtis Lighting Inc., Chicago, Illinois.

1. "Parade of Lighting Progress." ILLUMINATING ENGINEERING, Vol. XLVI, page 14, January 1951.

Figure 1. Installation of acoustic baffles at the Hinsdale Township High School.

Figure 2. Brightness values at various points in the classroom and illumination level on desk tops.

The central channel is the larger size, enclosing the ballasts. The tubing sections require no threading and are secured by a simple turn of the fittings at the channel sides. These sections of tubing establish lampholder spacing, provide closed passage for wiring and unify the assembly for electrical grounding. The one-foot by eight-foot baffles consist of panels of acoustical material set in a metal frame. Both exposed surfaces of the acoustical material are perforated.

The ballasts, used in the sections, operate the lamps at approximately half brightness. Sections are factory wired so that all lamps on the window side of a classroom may be placed on one switch circuit and the remaining lamps in the room may be placed on another switch circuit or circuits. The electrical contractor may then provide switching so that the lamps on the window side may be turned off during brighter periods of the day. The lamps are 96-inch T-12 slimline, with single pin base and require no starters. The ballasts and the high voltage wiring are confined to the larger central channel. In new construction, the branch circuit outlet would probably be located at some point along this ballast channel. However, for convenience in either new or old construction, the building circuit conductors may enter any channel section.

Shielding

The acoustical panels running crosswise of the room, provide minimum shielding of 45 degrees for the pupils and 30 degrees for the teacher, the shielding angles being measured downward from a horizontal plane through the lamps. These same panels could easily be shifted to a point midway between the lamps in which case the minimum shielding would be 35 degrees from both ends of the room. The three-foot spacing of lines of lamps results in unusually uniform illumination over the desk area and in excellent diffusion and lack of shadows. Notice in Fig. 2, the illumination under the desks.

The quality of lighting over the desk area is comparable to that of indirect illumination while at the same time the brightness of the upper part of the room from normal viewing angles is much lower than it would be with either an overall luminous ceiling or a ceiling illuminated by indirect luminaires if such installations were to provide an equal quantity of light on the desks.

At each end of the room there are two rows of low brightness lamps on four-inch centers. These

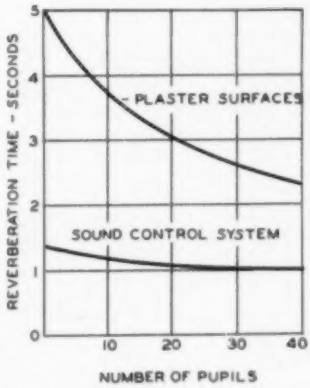


Figure 3. Maximum sound conditioning in a large room (Hinsdale Township High School) with dimensions 35 x 26 x 11 feet.

serve a dual purpose. They provide higher illumination on the chalkboard and rear wall than if the first and last rows of lamps were located close to these surfaces. They also assist in keeping the level of illumination at the front and rear desks comparable to that at the center of the room.

Comfortable lighting and good efficiency with this system are dependent on a satisfactory environment. The finishes of the ceiling, walls and floor and of the furnishings should be light in color and non-glossy.

Summary

Lighting is good when it combines high quality and adequate quantity. The comfortable quality of the illumination produced by the light and sound conditioning system described may be attributed to three "S" factors:

1. SOURCE — Fluorescent lamps operating at low brightness.
2. SHIELDING — The size and positioning of the acoustical panels which conceal the lamps from normal viewing angles.
3. SURROUNDINGS — The light colors of the room surfaces and furnishings.

The system provides unique features of packaging, installation, illumination, sound control and maintenance. Individual sections, factory-wired and folded for packaging, are extended and joined with other sections on installation. This provides support and control for continuous lines of light across most of the ceiling area.

The 96-inch fluorescent lamps operate at approximately half brightness to reduce reflected glare, brightness contrasts and brightness ratios, and to minimize shadows.

The baffles provide shielding of the lamps as well as acoustical control. The vertical position of the baffles reduces maintenance. The system makes very satisfactory utilization of the light and provides effective acoustical control.

High School Band Room Features High Level Lighting

The band room at the Lyons Township High School and Junior College, La Grange, Ill., has an average level of 70 footcandles on a horizontal plane three feet above the floor after six months of operation. Each of the luminaires is equipped with two 85-watt T-17 lamps. There are two rows of nine 5-foot luminaires and one row of seven. Brightness readings indicated on the photograph are in footlamberts and were taken from camera position. The brightness of white paper measured on several music racks ranged from 45 to 65 footlamberts.

Photo courtesy Curtis Lighting, Inc., Summit, Ill.

Daylighting in Classrooms

By R. A. BOYD

WHEN one considers the present day activity of children in schools it is evident that the visual environment must be arranged to accommodate all types of activity. One cannot limit a person's activity in a room or building and thereby expect to protect him from the dangers that are inherent to poor lighting. Consequently, it is the responsibility of the scientist to specify the characteristics of good daylighting for all activities and to describe clearly how these visual environments can be established, measured and maintained.

Although the importance of quality in lighting has been established, there is still a tendency to minimize it and talk principally of quantity. Possibly this is due to the fact that it is much more difficult to achieve good quality than it is to obtain quantity. Quality natural lighting can be provided through the use of optically designed fenestration materials. In many types of fenestration the brightness ratio, involving the brightness of the fenestration and the illumination of the task, is high. The best way to reduce the brightness ratios incidental to daylighting is to lower the fenestration brightness in the direction of the observer and at the same time raise the illumination of the task. This requires the use of a functional fenestration, that is, one that transmits light into the room in upward directions, together with proper reflectances for the room surfaces. From the point of view of efficiency and high quality, these surfaces should be as high in reflectance as is practical. The brightness ratios developed in the room are dependent upon the reflectances of the room surfaces and the amount of light incident upon those surfaces.

With non-functional fenestration materials such as clear flat glass some form of auxiliary brightness control devices are necessary to obtain quality daylighting. Some are diffusing, such as window shades, others are reflecting, as in the case of Venetian blinds. These auxiliary devices require considerable care and adjustment. Prismatic glass block have the preadjusted light control devices built into them.

Both quality and quantity in daylight are dependent upon several factors: the size of fenestration relative to the room, the transmission characteristics of the fenestration material, the room surface reflectances and the exterior daylight conditions. In many reports on daylighting, incomplete data are given on some of these factors. For examples, sky brightness is frequently recorded, but no data as to the exterior illumination on the fenestration are given. This illumination depends not only upon the sky conditions but also upon surrounding exterior conditions such as foliage, bare ground, pavement and buildings. Neglect of these influences can result in misleading conclusions.

The Daylighting Laboratory, built on the roof of one of the buildings at the University of Michigan, includes a full-scale experimental classroom, Fig. 1. Measurements presented in this paper were taken in this experimental classroom and two actual classrooms located at the Southside Junior High School, Kalamazoo, Michigan, and the Newton School, Newton, Massachusetts. Each of these classrooms has fenestration which consists of prismatic glass block above a clear sheet-glass vision strip. The Kalamazoo School also has a clerestory of prismatic glass block. Fenestration and room surface bright-

Figure 1. Full-scale experimental classroom is built on the roof of one of the buildings at the University of Michigan.

Condensation of a paper given at the I.E.S. Regional Meeting, Cincinnati, Ohio, May 25, 1951.
Author: Research Physicist, Engineering Research Institute, University of Michigan, Ann Arbor.

nesses are given in footlamberts, and task illuminations in footcandles.

Illumination measurements were made with corrected photocells which were connected to a Speedomax Recorder to eliminate personal errors in reading. The error in illumination measurements was not greater than 2 per cent. The brightness of the sky and fenestration was measured automatically by a direct-reading objective type instrument designed and built at the University of Michigan for the Daylighting Laboratory. None of the available brightness measuring instruments were considered suitable for this application. The brightness of the room surfaces, on the other hand, was determined by measuring the surface reflectance and incident illumination and also by use of the Luckiesh-Taylor Brightness Meter.

1. Experimental Classroom Daylighting Laboratory, University of Michigan, Fig. 2

(a) Dimensions:

Room Depth	24 Feet
Room Width	32 Feet
Ceiling Height	12 Feet

(b) Reflectivities:

Ceiling	88%
Average for Front Wall	63%
Average for Opposite Wall	71%
Average for Rear Wall	77%
Desks	48%
Floor	32%
Chalkboard—Green	21%
Tackboard—Tan	41%
Average—Entire Room	61%

(c) Ratio of Fenestration Brightness to Task Illumination:†

	*Sun and Clear Sky**	*Overcast Sky**
Exterior Vertical Surface Illumination	4250 Ft-c	1000 Ft-c
Date	5/5/51	5/17/51
Time (E.S.T.)	10:00 am	3:00 pm
Front Block Panel to Right Rear Task	5.0 to 1	5.5 to 1
Rear Block Panel to Right Rear Task	8.1 to 1	8.9 to 1
Rear Block Panel to Left Rear Task	3.1 to 1	3.0 to 1

(d) Brightness Ratios:‡

	*Sun and Clear Sky**	*Overcast Sky**
Block Panel to Adjacent Wall	1.8 to 1	1.6 to 1
Chalkboard to Wall Above	1.0 to 3	1.0 to 3
70% Task at rear desk to:		
Desk	1.5 to 1	1.5 to 1
Floor	2.5 to 1	2.0 to 1
Dado	1.8 to 1	1.3 to 1
Diversity of Task Illumination	2.5	2.7

2. Southside Junior High School, Kalamazoo, Michigan, Fig. 3

(a) Dimensions:

Room Depth	28 Feet
Room Width	28 Feet
Ceiling Height:	
Main Fenestration	11′ 0″
Clerestory	15′ 3″

(b) Reflectivities:

Ceiling	92%
Concrete Block Wall—Yellow	79%
Chalkboard—Green	21%
Tackboard—Tan	29%
Birch Woodwork	52%
Desks	45%
Tile Wainscot—Buff	60%
Floor Asphalt Tile	32%

(c) Ratios of Fenestration Brightness to Task Illumination:

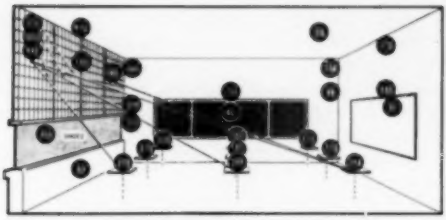
	Overcast Sky
Exterior Vertical Surface Illumination	1000 Ft-c
Date	5/10/51
Time (E.S.T.)	11:00 am 12:10 pm
Front Main Panel to Right Rear Task	5.7 to 1
Rear Main Panel to Right Rear Task	6.7 to 1
Brick Wall to Right Rear Task	7.3 to 1

†This ratio of fenestration brightness (in footlamberts) to task illumination (in footcandles) is used as a physical description of lighting quality; it is related to physiological adaptation.

*These values are for the vision strip shaded with Venetian Blinds, the slats being set to eliminate direct light from the sky. For the vision strip unshaded the ratio of sky brightness to rear task illumination would have been 15 to 1 or greater. For the case of overcast sky the illuminations at the remote side of the room would have been increased by 6 to 9 footcandles.

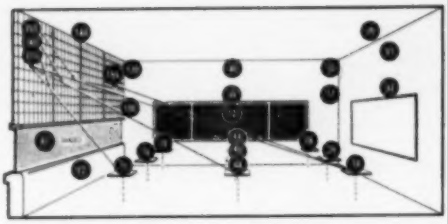
‡It will be noted from these data that the quality of the daylighting is high and the same for overcast and sun and clear sky conditions; more extensive laboratory data also confirm this. This is interesting in that, of the two characteristics of good daylighting the most important one, namely quality, can be definitely maintained.

If one considers the illumination of the working plane, the front wall, the ceiling and the opposite wall as indicated on these drawings it is apparent that they all have approximately the same value. This means that a working plane or task can be oriented in any way and its illumination will be substantially the same.



Daylighting Laboratory, Experimental Classroom, South Exposure
10:00 A.M., E.S.T., 5/5/51 SUN AND CLEAR SKY

Figure 2a.

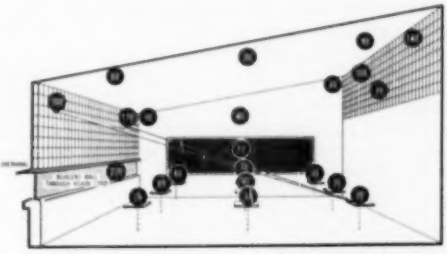


Daylighting Laboratory, Experimental Classroom, South Exposure
3:00 P.M., E.S.T., 5/17/51 OVERCAST SKY

Figure 2b.

(d) Brightness Ratios:

	Overcast Sky
Main Block Panel to Adjacent Wall	3.4 to 1
Clerestory Block Panel to Adjacent Wall	3.4 to 1
Chalkboard to Wall Above	1.0 to 3.3
70% Task at Rear Desk to:	
Desk	1.3 to 1
Floor	2.1 to 1
Dado	1.4 to 1
Diversity of Task Illumination	2.5



Southside Junior High School, Kalamazoo, Mich., Room 314, East Exposure
11:00 A.M.-12:10 P.M., E.S.T., 5/10/51 OVERCAST SKY

Figure 3.

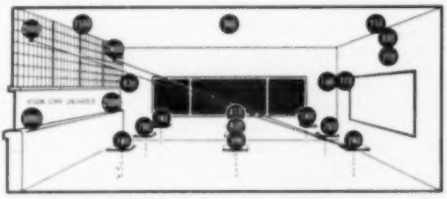
3. Newton School, Newton, Massachusetts, Fig. 4

(a) Dimensions:

Room Depth	23′ 4″
Room Width	33′ 0″
Ceiling Height	10′ 11″

(b) Reflectivities:

Ceiling	89%
Upper Walls	78%
Lower Walls	76%
Chalkboard—Green	18%
Desks	40%
Floor	28%

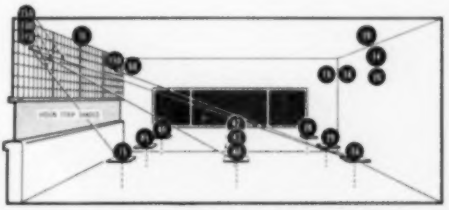


Newton School, Newton, Mass., Room 12, Southeast Exposure
10:50 A.M., E.S.T., 10/9/50 SUN AND CLEAR SKY

Figure 4a.

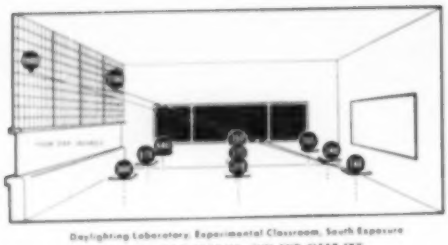
(c) Ratio of Fenestration Brightness to Task Illumination:

	Sun and Clear Sky	*Overcast Sky*
Exterior Vertical Surface Illumination	9000 Ft-c	1000 Ft-c
Date	10/9/50	9/19/50
Time (E.S.T.)	10:55 am	11:30 am
Front Block Panel to Right Rear Task	5.8 to 1	6.2 to 1
Rear Block Panel to Right Rear Task	8.3 to 1	10.6 to 1
Vision Strip to Right Rear Task	32 to 1	



Newton School, Newton, Mass., Room 12, Southeast Exposure
11:15-11:45 A.M., E.S.T., 9/19/50 OVERCAST SKY

Figure 4b.



Daylighting Laboratory, Experimental Classroom, South Exposure
1:30 P.M. E.S.T. 10/18/50 SUN AND CLEAR SKY

Figure 5.

These data also confirm the corresponding data for the experimental classroom. The Newton School readings for overcast sky with vision strip shaded, agree with the Laboratory data presented under item 1. The readings for sun and clear sky agree with those taken in the Laboratory classroom about the same time of year as shown on the following diagram.

4. Experimental Classroom, Daylighting Laboratory, University of Michigan, Fig. 5

(a) Dimensions:

Room Depth	24 Feet
Room Width	32 Feet
Ceiling Height	12 Feet

(b) Reflectivities:

Ceiling	75%
Average for Front Wall	63%
Average for Opposite Wall	69%
Average for Rear Wall	67%
Desks	48%
Floor	32%
Chalkboard—Green	21%
Tackboard—Tan	41%
Average Entire Room	56%

(c) Ratio of Fenestration Brightness to Task Illumination:

	Sun and Clear Sky	
Exterior Vertical Surface Illumination	8-9000 Ft-c	
	Vision Strip	
	100% Shaded	*Unshaded*
Date	10/18/50	10/18/50
Time (E.S.T.)	1:30 pm	1:20 pm
Front Block Panel to Right Rear Task	6.5 to 1	4.6 to 1
Rear Block Panel to Right Rear Task	11.2 to 1	7.9 to 1
Vision Strip to Right Rear Task	1.2 to 1	21.0 to 1

All of these results, presented for the Laboratory Classroom and actual school classrooms, indicate that quality daylighting can be obtained through the use of prismatic glass block; the quality being essentially the same for sun and overcast sky conditions. The high brightness ratio that is introduced by an unshaded vision strip can be eliminated by proper shading without substantially reducing the illumination throughout the room.

References

1. "The Control of Natural Light in Schoolrooms," Leland H. Brown; ILLUMINATING ENGINEERING, 34, 1939, pp. 606-620.
2. "The Design of Classrooms for High Level Daylight Illumination," Leland H. Brown; ILLUMINATING ENGINEERING, 36, 1941, pp. 411-424.
3. "Control of Natural Light in Classrooms," R.L. Biesele, Jr., W. E. Folsom and V. J. Graham; ILLUMINATING ENGINEERING, 40, 1945, pp. 590-621.
4. "Brightness Control in a Model Schoolroom," Willard Allphin; ILLUMINATING ENGINEERING, 41, 1946, pp. 21-34.
5. "Integrated Lighting for Classrooms," R. L. Biesele, Jr.; ILLUMINATING ENGINEERING, 41, 1946, pp. 805-827.
6. "Quality Lighting in Schools," Russell C. Putnam; ILLUMINATING ENGINEERING, 42, 1947, pp. 471-487.
7. "Classroom Fields of Vision," Allen S. Turner and Arthur A. Brainerd; ILLUMINATING ENGINEERING, 42, 1947, pp. 488-502.
8. "The Measurement of Illumination and Brightness in a Classroom," W. E. Folsom and R. L. Biesele, Jr.; ILLUMINATING ENGINEERING, 43, 1948, pp. 355-376.
9. "Daylight in Classrooms," R. L. Biesele, Jr.; ILLUMINATING ENGINEERING, 45, 1950, pp. 445-456.
10. "Recommended Practice of Daylighting," Illuminating Engineering Society, 1950.
11. "Glare Ratings," Ward Harrison, ILLUMINATING ENGINEERING, 40, 1945, pp. 525-557.
12. "Further Data on Glare Ratings," Ward Harrison and Phelps Meaker, ILLUMINATING ENGINEERING, 42, 1947, pp. 157-179.
13. "The Effect of Illumination Intensities Upon Speed of Perception and Upon Fatigue in Reading," Miles A. Tinker, *Journal of Educational Psychology*, 30, 1939, pp. 561-571.

DISCUSSION

R. C. PUTNAM*: The illustrations which accompanied Dr. Boyd's article are very informative and present in a very clear manner the brightness and illumination values developed in classrooms equipped with glass block fenestration. By comparing these values with the tables of limiting brightness ratios and limiting luminaire brightnesses as given in the American Standard Practice for School Lighting, it can be seen that the room fulfills the visual comfort requirement on overcast days. Under sun and clear sky conditions, however, the brightnesses developed in the glass block exceeds the limiting luminaire brightnesses as given in the American Standard Practice for School Lighting even though the brightness ratios are still within acceptable limits. In the visual zone from horizontal to 30 degrees above horizontal, the Standard Practice specifies that the brightnesses should not exceed 225 footlamberts where large areas are involved. The illustration for sun and clear sky conditions in this paper show glass block brightnesses ranging up to 2000 footlamberts which is eight times that recommended as a maximum value.

It should be kept in mind that the criterion of brightness ratio, valuable as it is in judging quality lighting, is only one of several criteria which must be met. Certainly areas as large as these fenestrations and with brightnesses as high as those recorded under sun and clear sky condi-

*Chairman, I.E.S. Committee on School Lighting, Professor, Case Institute of Technology, Cleveland, Ohio.

tions have an important effect on the comfort (or lack of it) of the installation.

The use of a ratio of fenestration brightness in terms of footlamberts to task illumination in footcandles as a measure of lighting quality is a new concept. The usual method is to assume an average task reflectance so that these ratios can be expressed as simple ratios of brightnesses.

It should be noted also that the reflectances of the side walls in the different installations are given as 71, 76, 77, and 78 per cent whereas the American Standard Practice for School Lighting specifies 70 per cent as the maximum value for such areas.

Dr. Boyd refers to an automatic direct reading objective type brightness measuring instrument. There is a real need for such an instrument and it would be very helpful if Dr. Boyd would describe his development along these lines.

R. A. Boyd*: The maximum brightness of 225 footlamberts, that Professor Putnam cites in his discussion, pertains to luminaires. It is a vague limitation in that the corresponding field brightness and task illumination are not stated. Various researches have shown that brightness ratios are of extreme importance in quality lighting and visual comfort. In daylighting through the use of prismatic glass block the quantity of illumination is not a constant as in the case of artificial lighting; therefore, brightness ratios must be used as one measure of quality. As Professor Putnam states brightness ratio is only one of several criteria that must be met. It is quite likely that additional researches will show that there is a maximum brightness for visual comfort even though brightness ratios are controlled but it is inconceivable that its value is 225 footlamberts. Mr. H. L. Logan in his research relating to the brightness characteristics of natural luminous environments has found that brightnesses of several thousand footlamberts are not uncomfortable. The very fact that man has good vision outdoors is evidence that brightness alone does not define a good visual environment.

The ratio of fenestration brightness to task illumination was used instead of the ratio of fenestration brightness to task brightness because it involves two quantities that can be measured accurately. Besides, the quotation of task illumination does not involve the uncertain characteristics of the task, namely, reflectivity, diffusion and contrast.

It is difficult to say why the American Standard Practice for School Lighting specifies 70 per cent as a maximum value for the reflectivity of the classroom walls. Presumably it relates to the brightness ratio between task and surround; especially where the task is a wall-chalkboard. In that case, the reflectivity of the wall adjacent to the chalkboard should not be greater than three times the reflectivity of the chalkboard if the 1 to 3 brightness ratio is to be maintained, but this in itself does not establish a 70 per cent limit. From the point of view of diffusion of light the reflectivity of the walls should be as high as is practical from a maintenance point of view.

A description of the objective-type brightness meter used in this work will be given in a later paper after the development of the instrument has been completed.

*Author.

Low Depreciation In Experimental Installation

Two-lamp 40-watt luminous indirect luminaires are used in an experimental installation at the North Glendale School, Glendale, Mo. With the totally enclosed unit—translucent lower plastic and clear upper plastic—the initial level of illumination was 53.9 footcandles and after nine months, 46.5, amounting to a depreciation of only 13.7 per cent.

Brightness ratios are: luminaire to acoustical tile ceiling, 1:2.5; task to desk, 1:1.6; task to floor, 1:6; and luminaire to chalkboard, 1:60.

Photo courtesy Day-Brite Lighting, Inc.

A.I.A. File No. 31

Lighting a Storefront Identification Sign

LIGHTING OBJECTIVE: To identify a small store on a main shopping street so it attracts attention tastefully.

Installation at Harris Brothers
Genesee Street, Utica, New York.

General Information: The three-faced sign has a total height of 13½ feet and projects approximately 5 feet out from the building with 3-foot wide faces. Letters on the sign are cut from .250-inch blue Plexiglas and are mounted on white translucent Plexiglas panels. The letters in the name HARRIS are 10 inches high with 2½ and ½ inch wide strokes.

The upper facade (12½ x 14½ feet overall) is made of corrugated and flat sheets of white translucent Plexiglas except for the 5 by 8-foot clear display window.

Lighting Installation: The sign is illuminated by 172 feet of 3500K 15 mm cold cathode tubing totaling 3750 volt-amperes with auxiliaries. The storefront employs 42 8-foot 3500K 25mm cold cathode lamps on 6 and 8-inch centers totaling 1836 volt-amperes with auxiliaries.

Sign brightness is 430 footlamberts with a resultant visibility distance of about 500 feet.

Installation designed and installed by Everett Hall and Son, Utica.

Illumination data submitted by J. C. Bannigan, Niagara Mohawk Power Corporation, Utica, New York as an example of good lighting practice and to aid in the design of similar installations.

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A.I.A. File No. 31

Stroboscopic and Flicker Effects from Fluorescent Lamps

By ARTHUR A. EASTMAN
JOHN H. CAMPBELL

THE INVESTIGATION reported in this paper was prompted by what the authors believe to be a general misconception as to the actual amount of cyclic flicker from fluorescent lamps, and its effects. Cyclic flicker from fluorescent lamps may sometimes be seen by looking at the ends of the lamps with slightly averted vision. Stroboscopic effects can be seen by observing moving machinery parts such as gears. Formulas are developed which will rate different lamps and circuits in the order of their effects. It will be shown that the stroboscopic and flicker effects from some filament lamps are about the same as with some fluorescent lamps.

Flicker Measurement of Light Sources

As a preliminary to the investigation, a quantitative method for determining the cyclic variation of the light output of fluorescent and filament lamps was needed. Since the light output consists of two parts, a steady component and a varying component, a convenient method had to be devised to show both parts simultaneously. Referring to Fig. 1, vacuum photocells were used as the means of detecting the light output. In conjunction, a cathode follower stage was employed in each photocell probe to avoid capacitive pick up and allow more flexible use of the photocell probes. The outputs of the photocells were coupled to the oscilloscope through an electronic switch. This arrangement made possible the observation of two light sources at the same time to determine their relative flicker and phase relation. By placing one of the cells in the dark, the total light observed by the second cell could be shown on the oscilloscope, the trace of the first cell acting as the base line.

Lamps and Circuits

Fluorescent lamps vary in cyclic flicker depending upon the color (type of phosphor used) and the circuit used to operate them. In the early days of fluorescent lighting, all lamps were operated singly by means of a series reactor and a starting switch, Fig. 2 (A-1).

Lamps such as the 40-watt type operated on single lamp ballasts produced a 50 per cent lagging power factor. This characteristic was not desirable in large installations and power factor was increased by applying capacitors to individual ballasts or at the panel board. It should be pointed out that the cyclic flicker was not considered objectionable for most applications and correction of line power factor by means of separate capacitors did not reduce cyclic flicker. In a few installations, fixtures were installed on three-phase circuits to correct cyclic flicker, but this added to wiring costs. However, a much more efficient method of power factor correction resulted from the development of the split-phase, two-lamp, preheat-type ballast. This circuit produced a high power factor by operating one lamp on a leading power factor circuit and the other on a lagging power factor from a common transformer, Fig. 2 (B-1). Although power factor correction was the prime purpose of the two-lamp ballast, it also provided some correction of cyclic flicker by operating the two lamps on opposite phases. The resulting illumination could be shown by measurement with photocells and oscilloscope to be more uniform than that from lamps operated on single lamp ballasts. Therefore, more attention was given to cyclic flicker by comparing single and two-lamp operation. When instant-start, split-phase ballasts were designed, such as the slimline group, a higher voltage was required to start the lamps, Fig. 2 (C-1). The optimum ratio of inductive to capacitive reactance for

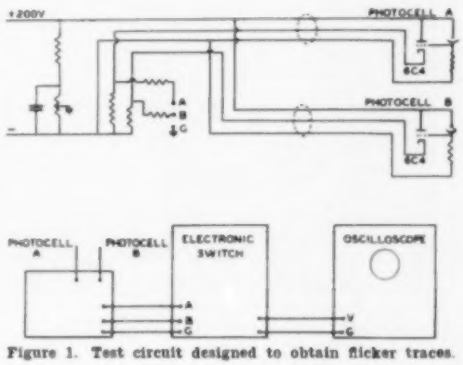

Figure 1. Test circuit designed to obtain flicker traces.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 27-30, 1951, Washington, D. C. Authors: General Electric Co., Nela Park Engineering Division, Cleveland, Ohio.

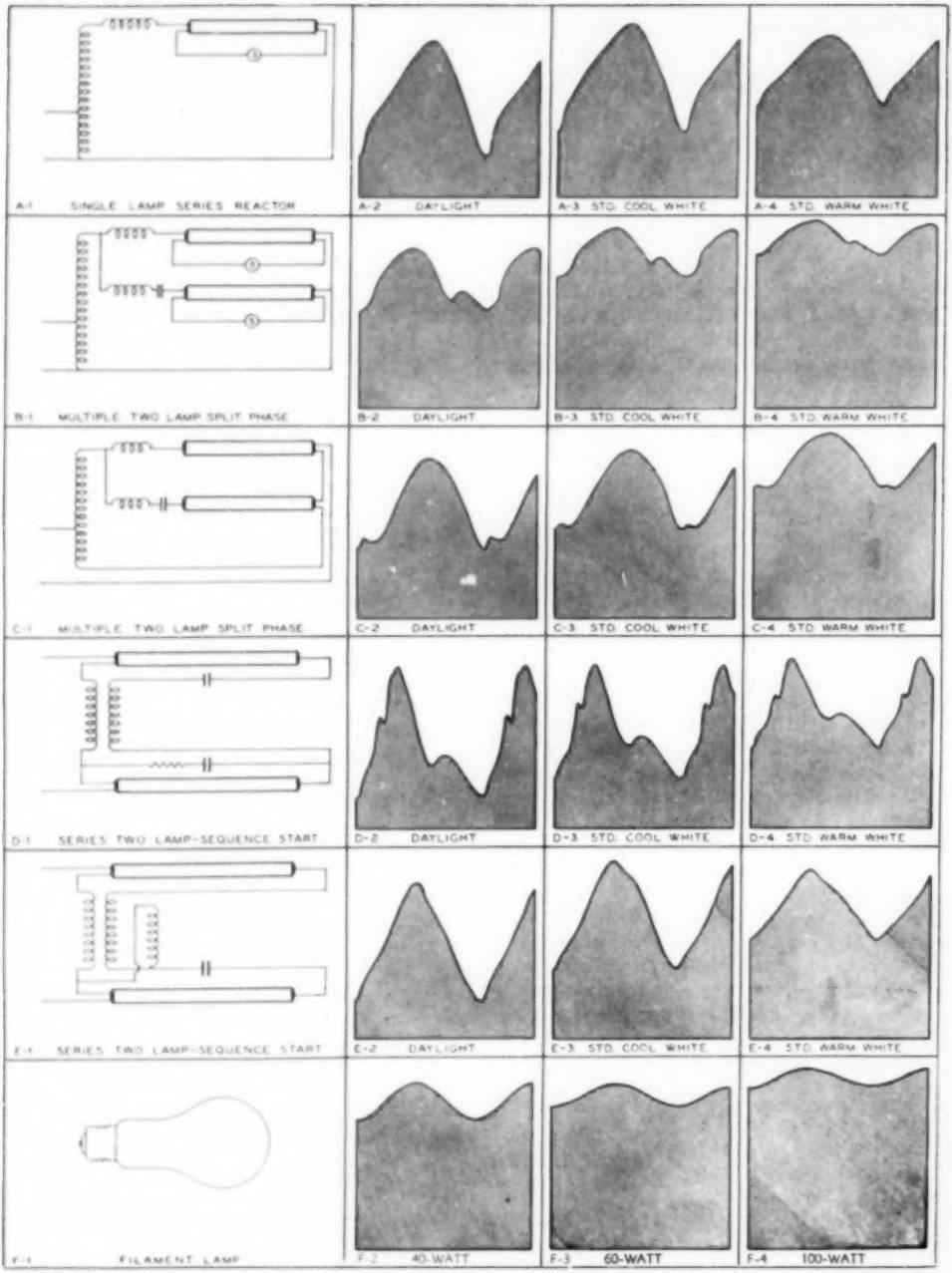

Figure 2. Typical circuit diagrams for the operation of fluorescent lamps and the resultant waveforms of the light from daylight, standard cool white, and standard warm white lamps. Also waveforms of light from 40, 60, and 100-watt filament lamps.

proper lamp regulation and wave shape resulted in a closer phase relation between the two lamps and cyclic flicker approached single lamp operation.

The now popular sequence-starting, series-operating ballasts resulted in reducing the size, weight and cost of slimline ballasts, but since lamps operate in series there is little or no correction of cyclic flicker. In fact, one sequence-start series circuit shows an increase in flicker over a single lamp because of current wave shape distortion. Two types of sequence-start series ballasts now on the market are illustrated by the schematic diagrams of Fig. 2 (D-1) and Fig. 2 (E-1).

Light Output Wave Shapes

Fig. 3 shows two photographs of typical traces as recorded on the oscilloscope. The trace at the left shows light variation from a single daylight lamp operated on a reactor type ballast and the trace at the right illustrates light variation from two standard warm white lamps operated on a preheat type split-phase ballast. These two photographs represent the extremes of high and low flicker with present phosphors and circuits. The flicker traces shown in Fig. 2 corresponding to various circuits and lamp colors were obtained from photographs taken during the test.

Table I shows the per cent flicker and phase angle corresponding to various lamp color and circuit combinations for the 40-watt lamp. Per cent flicker from filament lamps of various sizes is also shown for comparison of the two light sources.

Per Cent Flicker

Per cent flicker in each case represents deviation from the mean of maximum and minimum light output as measured from the zero light base line which can be expressed by the following equation:

$$\text{Per Cent Flicker} = \frac{\text{Max.} - \text{Min.}}{\text{Max.} + \text{Min.}} \qquad (1)$$

The daylight, standard cool white and standard warm white phosphors in lamps operated on the same ballast show a range of per cent flicker values. This difference in per cent flicker is due to the differences in the decay time of the various phosphors. The same lamps will show a difference in per cent flicker depending upon the ballast circuit employed. When two lamps are operated on a split-phase ballast such as shown in Figs. 2 (B-1) and 2 (C-1), the resulting illumination will vary in per cent flicker depending upon the phase angle between the two lamps. A 90° phase angle produces maximum correction, but other considerations in ballast design make it impractical to design for a 90° separation. In referring to Table I, it will be noted that the flicker of lamps operated on the low voltage preheat ballast where the lamps are 68° apart is about one-half that of the higher voltage multiple instant-start type where the phase angle is only 35°. Any correction obtained with single lamp or series ballasts is dependent upon the decay rate of the phosphor and the operating current wave shape.

Flicker Index

Per cent flicker of any given light source can be measured with reasonable accuracy but these data are not necessarily indicative of the way in which the human eye responds to objects illuminated by the flickering light sources. It is therefore apparent that proper evaluation of flicker depends upon

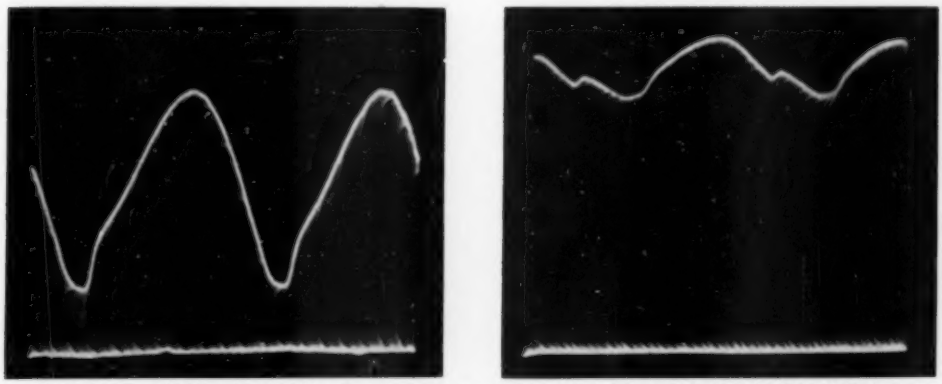

Figure 3. Two photographs of light output traces as recorded on the oscilloscope. Left — single daylight lamp operated on a reactor type ballast. Right — two standard warm white lamps operated on a preheat split-phase ballast.

TABLE I.

Circuit	40-w Daylight Per Cent Flicker	40-w Daylight Flicker Index	40-w Standard Cool White Per Cent Flicker	40-w Standard Cool White Flicker Index	40-w Standard Warm White Per Cent Flicker	40-w Standard Warm White Flicker Index	Phase Angle
Single lamp series reactor preheat start Fig. 2 (A-1)	58.4	0.152	44.7	0.117	27.5	0.077	68°
Multiple two-lamp split-phase preheat start Fig. 2 (B-1) ..	24.0	0.080	15.7	0.046	9.9	0.027	28°
Multiple two-lamp split-phase instant-start Fig. 2 (C-1) ..	39.1	0.122	31.2	0.097	16.9	0.048	
Series two-lamp sequence-start Fig. 2 (D-1)	65.5	0.203	53.3	0.140	35.5	0.090	
Series two-lamp sequence-start Fig. 2 (E-1)	59.8	0.167	44.0	0.125	26.9	0.076	

	Per Cent Flicker	Flicker Index
40-watt filament	12.2	0.043
60-watt filament	6.8	0.027
100-watt filament	5.1	0.009

a flicker index which can rate different wave forms in the same order as the human eye.

When a light source varies in brightness, either regularly or irregularly, it is said to flicker. All common sources of light produced with alternating current are flickering lights. The tungsten filament of the incandescent lamp flickers as it heats and cools with each change of direction of the flow of current. With 60-cycle current, 120 pulses of light per second are produced as the current changes direction 120 times each second. In gaseous discharge lamps, such as neon tubing, and in fluorescent lamps, a pulse of light is also produced with each pulse of current, and flicker results.

An incandescent tungsten filament does not have time to cool completely as the current changes direction, so the light emitted has a flickering part plus a steady part. The light from the neon tubing goes out entirely with each reversal of current and a strong flicker is produced.

The light from the fluorescent lamp is also partly flickering and partly steady. The amount of flickering light with respect to the steady light varies with the decay rate of the phosphor used and with the ballast circuit. Over most of the length of the lamp, the flicker rate is 120 flashes per second with 60-cycle operation. At the ends of the lamp each alternate flash is comparatively weak. This gives an effective rate of 60 flashes per second. When flicker is noted in fluorescent lamps, it is this end flicker which is seen.

The human eye cannot detect a flicker of 120 flashes per second. Fusion of the flashes into a steady sensation occurs at a rate much lower than this. Hecht and Shlaer[1] in 1936 showed flicker fusion frequencies up to 63 flashes per second for a 16-degree area of high brightness. Other experimenters also show that fusion frequencies in the neighborhood of 60 flashes per second are found only with large areas and high brightnesses. Under most conditions, flicker can be detected more readily with peripheral vision than with central vision. This accounts for the fact that when the end of a fluorescent lamp is directly observed, flicker cannot generally be seen, but it can be seen sometimes with slightly averted vision. The same effect can be observed when viewing an incandescent lamp operating at 25 cycles. The effect is usually more pronounced since flash frequency in this case is 50 per second rather than 60.

Many investigators have used only on and off flicker with the light and dark periods equal. This gives a square wave of light output on the oscilloscope. Some have investigated the effect of different light-time ratios. Crozier,[2] Cobb[3] and others have found that when the light time of the cycle is large, fusion occurs at a lower frequency than when the light time is small compared with the dark time. Ives[4] found that the square wave gave a more pronounced flicker than the sinusoidal and other wave forms.

It can be seen from this discussion that the observance of flicker is dependent not only on the frequency of the flicker, the area of the source and its brightness, but also on the wave form. The light from incandescent lamps varies in a nearly sinusoidal wave, while that from fluorescent lamps is distorted and may take any number of forms.

The direct or peripheral observation of the flickering end of a fluorescent lamp can be avoided by proper shielding. (The principal reason for shielding is, of course, to avoid high brightnesses in the field of view.) However, another effect of flicker which cannot always be avoided is the stroboscopic effect on moving machinery or merely the fingers waved under the light.

It is well known that a single lamp will give a greater stroboscopic effect than will two lamps arranged in a split-phase circuit. But, there has been no way to evaluate flicker on an entirely satisfactory basis. Formula (1), per cent flicker, will often give a satisfactory rating, but there may be observable differences between two lamps or two circuits even though the per cent flicker is the same. There is a need for a simple method of assigning flicker indexes to the light from different circuit and phosphor combinations so that the combinations can be directly compared as to their effective-

ness in minimizing the direct observation of flicker and the stroboscopic effect.

A flicker index should rate different wave forms in the same order as the human eye. That is, a square wave form should have a higher index than a sinusoidal wave. A wave form with a large dark portion should have a higher index than one with a large light portion. Light from a source having a small steady component should have a higher flicker rating than light with a large steady component. These requirements are met by a simple formula developed from the examination of oscilloscope tracings of wave forms and checked by direct observation.

Fig. 4 shows a typical curve of flicker from the end of a fluorescent lamp. If there were no flicker, the curve would be simply a straight line a certain distance, I, above the base line, and I would represent the intensity or brightness. With the flicker curves, I_{ave} is determined by dividing the total area under the curve, A_t, by the length of the cycle, L. After the average line is drawn in, the area under the curve is seen to be divided into two parts, A_a, above the line and A_b, below the line. A flicker index, F, is determined by dividing the area above the average line by the total area under the curve.

$$F = \frac{A_a}{A_t} \qquad (2)$$

This formula will rate the different wave forms in the same order as the eye, and can be checked by direct observation. Any formula which depends only on maximum, minimum, and average intensities such as (1), per cent flicker, will not differentiate between the wave forms shown in Fig. 5. These forms all give the same average brightness and they are all rated at 100 per cent flicker, but the flicker index values are not the same. The flicker index gives ratings from zero to one, with zero for a steady light. One is approached with a square wave with a large dark portion of the cycle. A square wave with equal light and dark portions and no steady component, has an index of 0.5. The

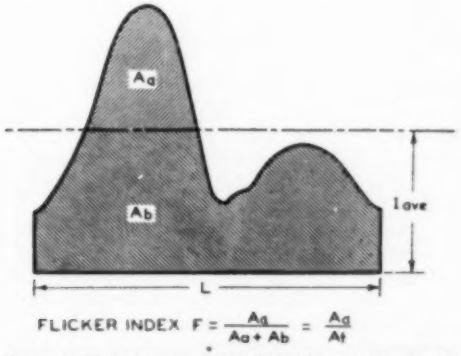

Figure 4. Typical curve of end flicker for a standard cool white fluorescent lamp showing method of calculating flicker index, F.

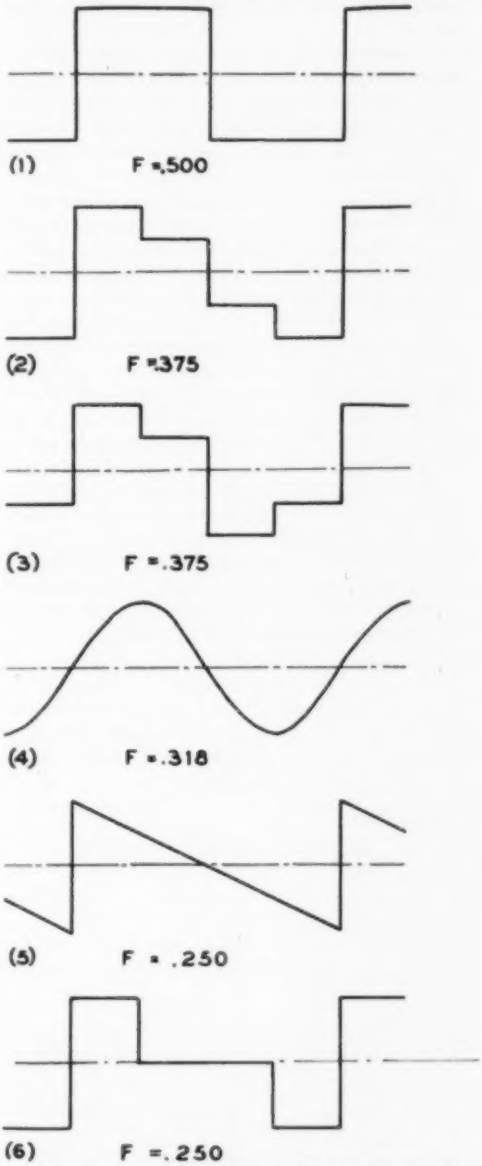

Figure 5. Various waveforms all with the same average and all having 100 per cent flicker, but differing in flicker index.

index becomes smaller with the addition of steady light. The index will not differentiate between the same wave form at different frequencies. This is not particularly important, however, as two wave forms which are shown to be different at one frequency will also be different at any other frequency.

Checking of the flicker index formula was accomplished by using the set-up diagrammed in Fig. 6. This is similar to the arrangement used by Ives[4] in 1924. Each wave form (Fig. 5) was plotted on polar coordinate paper and then transferred to a cardboard disk. The disk was rotated in front of a slot (covered with flashed opal glass) in a light box. The slot was radial to the disk and was five degrees wide. As the flicker disk rotated, the light coming through the slot was interrupted according to the shape of the disk. This interrupted, or flickering, light illuminated a 1½-inch diffusing disk in the center of a large white screen. The design of the disk and speed of rotation was such that the flash frequency was kept constant at 60 per second. Observers sat with their eyes 18 inches in front of the flickering spot which was adjustable in brightness.

Since the appearance of flicker is to a large extent dependent on brightness, measurements were made by adjusting the brightness of the spot until flicker was just observed. Flicker would appear at lower brightnesses for those wave forms with high flicker indexes than for those with low indexes. Readings were always taken by having the experimenter raise the brightness of the spot until the observer signalled that flicker was apparent. This method was found by Crozier[2] to give more reliable results than reducing the brightness until flicker was not seen.

Results for several observers are shown in Fig. 7. The flicker indexes are plotted against the brightness required to just see the flicker. Since the absolute brightnesses varied considerably with different observers, the brightness values are given in per cent of the brightness required to just see the flicker from the square wave (No. 1). It is seen that the expected relationship exists, in that as the flicker index decreases the brightness increases.

After the formula was checked with the wave forms shown in Fig. 5, flicker disks were made for the end flicker wave form, Fig. 4, and the wave form of C-2, Fig. 2. The wave form C-2 was observed at half its normal frequency which gave 60 impulses per second. The results given in Fig. 7 show agreement with the other wave forms tested. Since the end flicker varies greatly with the distance from the end of the lamp, only one typical trace was used.

The flicker indexes for the wave forms shown in Fig. 2 are given in Table I. The index values rate the different wave forms in the same order as the per cent flicker values, but the ratings are more nearly in accordance with the response of the eye. However, it should be emphasized that the flicker of the center portion of fluorescent lamps cannot be seen when the lamps are operated on 60-cycle

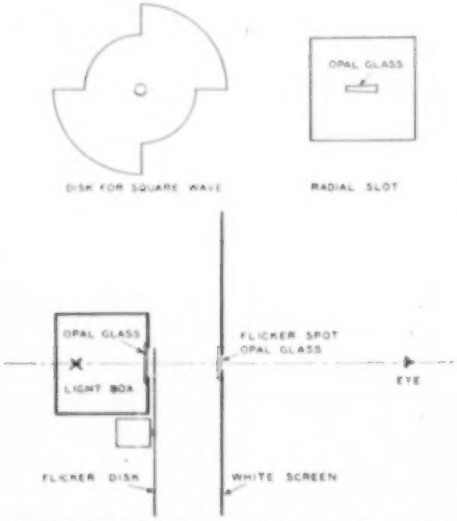

Figure 6. Schematic diagram of apparatus used to produce any desired waveform for a flickering spot.

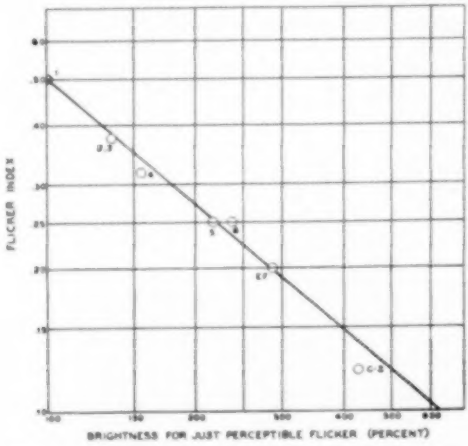

Figure 7. Flicker Index vs. Brightness for just perceptible flicker for a variety of waveforms. Nos. 1 to 6 refer to waveforms shown in Fig. 5, EF refers to Fig. 4, and C-2 refers to Fig. 2, C-2. Brightness for just perceptible flicker for square wave, No. 1 is 100 per cent.

current.

Different indexes are found for the three colors of lamps. These indexes were also checked by direct observation of the flicker spot. The differences, of course, are not due to the color since the oscilloscope trace would not show such differences. As stated previously, the differences are apparently due to the decay characteristics of the phosphors used to produce the different colors. It is of interest to note that Hecht[1] could find no difference in flicker response throughout the visible spectrum for all brightnesses in the range of photopic vision.

Stroboscopic Effect

The stroboscopic effect from flickering light can be observed with either rotating or reciprocating motion of machinery. With rotating parts, cogs or spokes may appear to move slower than they actually are, or even appear to move in the opposite direction. With a reciprocating part, several parts may be observed instead of just a blur when the part is moving. Whether this stroboscopic effect is significant or not depends upon the speed of the moving parts being illuminated. The flicker rate of the light source and the speed of rotating parts must be in exact synchronism to make the parts appear stationary while any deviation from this relationship will show motion.

The greatest stroboscopic effect is with gaseous discharge tubes especially designed for giving sharp flicker at any desired frequency. They are used to apparently stop motion of moving machinery so that the performance of the machine may be studied. The greatest stroboscopic effect from a fluorescent source may be from a single lamp or from two lamps operated on a sequence-start series ballast. The least stroboscopic effect from fluorescent lamps is obtained with multiple two-lamp, split-phase circuits. However, differences in stroboscopic effect with the different circuits may be less than the differences observed with different lamp colors.

For example, the flicker indexes for the standard warm white lamps operated on the multiple two-lamp, split-phase circuit of Fig. 2 (C-1) and the series two-lamp sequence-start circuit of Fig. 2 (E-1) are 0.048 and 0.076 respectively, (Table I). But, the index for the standard cool white lamp operated on the circuit of Fig. 2 (C-1) is 0.097. It should also be noted in Table I that the indexes for some fluorescent lamps and circuits are lower than the indexes for the 40-watt filament lamp.

To study the effect of various circuits and colors of lamps, a stroboscopic disk was prepared. It could be rotated at various speeds. Several systems using different ballast circuits (Fig. 2) were set up so that rapid switching from one to another could be effected. With the stroboscopic disk spinning, two systems at a time were compared by watching the stroboscopic effect while the systems were alternately turned on and off. In this way, by successive comparisons, individual systems could be arranged in their order of stroboscopic effect.

No quantitative data could be obtained by this method, except very rough estimates, but qualitatively the systems were arranged in the same order as indicated by the flicker indexes calculated from the oscilloscope traces, (Table I).

Conclusions

It would seem that the proposed flicker index would have particular value in the study of phosphors and also in the study of various circuit and ballast designs. It is a simple formula easy to apply and appears to fulfill the principal requirements of such a formula.

Flicker from fluorescent lamps appears to be of only academic interest for the great majority of lighting applications since the human eye cannot detect 120-cycle flicker. While the 60-cycle flicker at the extreme ends of the lamp can be detected with averted vision, the normal shielding of most fixtures eliminates this factor from consideration.

Stroboscopic effect is difficult to evaluate since each installation introduces variables such as type of motion and speed of moving parts. Warm white lamps operated on the 40-watt split-phase preheat ballast, Fig 2 (B-1), produce the least stroboscopic effect on single phase power systems. However, in the great majority of installations, stroboscopic effect causes no difficulty even with the sequence-start series ballasts. In the few critical installations, the choice of ballasts need not be limited since fixtures can be operated alternately on three phase power with maximum correction.

Acknowledgment

The authors wish to acknowledge the contribution to this paper by Harry E. Schultz of the Engineering Division at Nela Park. His work in developing the circuit used (Fig. 1) for obtaining flicker traces of the various lamp and ballast combinations provided a valuable short cut in obtaining data.

References

1. Hecht, S. and Shlaer, S.: "Intermittent Stimulation by Light. V. The Relation Between Intensity and Critical Frequency for Different Parts of the Spectrum," *Journal of General Physiology*, Vol. 19, p. 965 (1936).
2. Crozier, W. J., and Wolf, E.: "Theory and Measurement of Visual Mechanisms. V. Flicker Duration and Critical Intensity for Response to Flicker," *Journal of General Physiology*, Vol. 24, p. 635 (1941).
3. Cobb, Percy W.: "The Dependence of Flicker on the Dark-Light Ratio of the Stimulus Cycle," *Journal of the Optical Society of America*, Vol. 24, p. 107 (1934).
4. Ives, H. E.: "Critical Frequency Relations in Scotopic Vision," *Journal of the Optical Society of America*, Vol. 6, p. 254 (1924).

DISCUSSION

E. W. Bitzer*: I am very glad to discuss the interesting paper by Messrs. Eastman and Campbell. It is timely and worthwhile particularly because it presents new data on the instant start and series types of ballasts which have not been discussed before the Society.

I recall the tremendous amount of attention given to stroboscopic and flicker effects 11 years ago and I believe it was given more attention then than was proper. I am pleased to note that the authors are again aware of the hazard of over-emphasis and that they are cautioning us in the Society to take a conservative view of it.

People see things intermittently and most of the human race are entirely unconscious of flicker or stroboscopic effect from even a single fluorescent lamp on 60-cycle power. Most people are unaware of flicker even when they view motion pictures. We have been using single-lamp fluorescent applications now for over 10 years in many different lighting applications without difficulty. There are hundreds of thousands of new series type Slimline and instant-start ballasts in use with apparently no difficulty so I wish to confirm the authors' opinion that, in general, we need not worry about the difficulty even though these new ballasts do result in increased flicker and stroboscopic effect in the fluorescent lighting system.

The use of "per cent flicker," which is determined by maximum and minimum light output during the cycle, is misleading as far as the human eye is concerned and I am pleased to note that the authors emphasize what they term the "flicker index." This is similar to a conclusion we drew some years ago. Our own publications referred to "the ratio of light output during the cycle above mean average to the total output at mean average." This is about the same as the Eastman-Campbell term, "flicker index," and measurements we made some years ago check almost exactly with the ones they have recently taken. For example, in our system the 40-watt incandescent lamp had a relative value of 7, the two-lamp ballast with White fluorescent lamps was 9 and our single ballast lamp operation gave us a value of 19. Their value for the 40 watt incandescent lamp was .043 and if we were to give this a value of 7 and if we take their values for Cool White, than their flicker index for two-lamp ballasts becomes 7.8 and for the single-lamp operation, their value becomes 19 which is the same as our measurement made some years ago.

The authors mention the use of three-phase power and I believe that more emphasis could be given to the use of that system in places where flicker or stroboscopic effect are more important problems. In industrial lighting, where this is important, we frequently encounter three-phase power for the operation of motors and machinery so that I believe it will be worthwhile to advocate three-phase lighting quite widely in industrial operations where high speed rotating machinery is involved and where other apparatus, such as punch presses, weaving machines and the like, are used. Either single or two-lamp ballasts may be applied and if the lamps are mounted high, alternate rows of lamps may be operated on alternate phases. Where the lamps are low, particularly for local lighting, then arrangements should be made so that individual fluorescent lamps operate on alternate phases.

Glenn A. Fry**: The flicker index proposed will probably encounter difficulty when it is applied to a wave-form consisting of alternating high and low maxima. This sort of wave-form could undergo gradual transformation to a form in which the alternating maxima are of equal height. This, in effect, the *frequency* of cycles would become doubled. One can conceive of such a transformation in which the flicker index remains constant. It should not be claimed for the index that one can always predict the effect on the eye from the flicker index. A critical test for the index could be found in attempting to evaluate the flicker at a point a short distance from the center of a two-tube installation, with the maxima for the two tubes completely out of phase.

The wave forms in Fig. 5 have no secondary maxima or minima and it can probably be concluded that a high correlation would exist between the flicker index and visibility of flicker for wave-forms of this category. However, wave-forms with secondary maxima and minima are actually encountered in fluorescent lighting.

The use of a visual method of evaluating the flicker index in different types of fluorescent installations has not been proposed and inasmuch as the wave form of a light output has to be measured to assign a numerical value to the index, the question might be raised whether a specification of the index ought to be supplemented by a diagram of the wave-form. Visual inspection of the wave-form to determine the presence of secondary maxima and minima would help one decide whether the index could be used in predicting the visibility of the flicker.

Ernst Simonson*: The study by Messrs. Eastman and Campbell was undertaken mainly for a practical purpose, but has also interesting theoretical aspects. It is concerned with the effect of the light:dark ratio on the flicker fusion frequency (*f.f.f.*). The light:dark ratio is one of the fundamental variables of the *f.f.f.*, but comparatively few thorough studies have been reported in view of the tremendous literature on brightness and area effects. So far, the light:dark ratio was varied using rectangular or nearly rectangular wave forms. The authors approach the problem from a new angle by variation of the wave form. Although no investigations of different wave forms at the same brightness were made, it can be implied from Figure 7 that marked effects on the *f.f.f.* would result. In general, the results seem to corroborate the hypothesis that the *f.f.f.* is determined by the refractory period of the visual elements and are in agreement with recent investigations by Dr. Winchell and myself (in press in the *Journ. of Appl. Physiology*). A systematic investigation of the effect of the wave form on the *f.f.f* at various levels of brightness will be important for the theory of the *f.f.f* as well as its application for the measurement of visual fatigue, and it is hoped that the authors will extend their research in this area.

E. M. Strong**: In the early 1940's when fluorescent lamps were very new the questions which the authors discuss here interested me and I devised a simple means for getting oscillograms similar to these of the paper. Lacking other than very ordinary audio amplifiers, the problem of getting the variation in light with respect to true zero was solved by interposing between photo cell and light source a toothed disk; this acted as a "chopper" and provided a carrier frequency of about 2000 cycles which the amplifier could

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**Cornell University, Ithaca, N. Y.

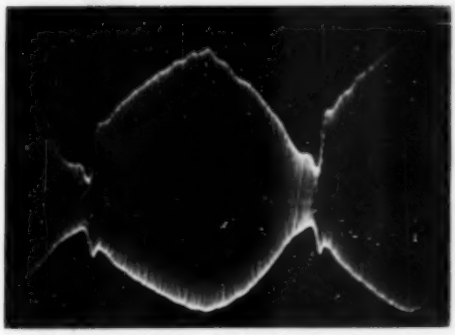

Figure 1 (discussion). Oscillogram of a 15-watt Daylight lamp (1930) taken by Prof. E. M. Strong.

handle. The authors accomplish the same end by "chopping" the photocell current electronically instead of by "chopping" the light mechanically.

The behavior of the then few phospors, of R, L and C ballasts and tulamp ballasts, as well as comparisons with incandescent lamps having concentrated or distributed filaments of different thermal mass were investigated. These were reported in an AIEE Student Branch paper, by one of my students who extended the first study with this equipment, but not otherwise published.

I agree that at 60 cycles the cyclic flicker seldom is troublesome simply as flicker; it is the stroboscopic effect which creates trouble. Consequently it seems not especially useful to argue whether or not the authors' concept of "flicker factor" may be valid, even though I feel dubious about it beyond the tests they explored.

It is important that a useful measure of the stroboscopic feature be devised and I believe this is more feasible by some kind of visibility test than by mathematical process. Perhaps this might be set up using a white disk driven by a self-synchronous motor so that a number of differently oriented black test objects such as the parallel bars popular with the authors or the international Landolt ring, spaced equidistant from the center of the disk could be viewed by an observer. Visibility readings on one of the test objects, taken with the disk illuminated by the light source to be rated, would then be obtained, first with the disk rotating synchronously and then at standstill. The ratio of these readings would provide a "strobe factor" ranging from unity for an ideal stroboscopic source (like a Strobotac) to zero for a steady d-c light. This at least provides a readily measured and understood quantity; one directly related to that aspect of lamp flicker which is most of concern to us.

JAMES H. MCCULLOCH[6]: So much propaganda has been circulated concerning this subject as applied to various ballast circuits that the factual studies reported in this paper are deserving of much more than the usual polite "congratulations to the authors."

Their proposed "Flicker Index" makes available, for the first time, a seemingly reliable method of numerical comparison of various sources, and seems to permit the pricking of many of the above mentioned propaganda bubbles.

It is to be hoped that this new tool may be used further, in settling beyond the reasonable shadow of a doubt the question of the influence of relative amounts of flicker on the human eye when it is not fixedly staring at a laboratory flicker device. Eye movements during reading may or may not produce a stroboscopic-like impression under illumination having a high flicker index. The work of these authors makes it possible to open quantitative studies of the subject.

The Benham's Top effect, noticeable under some fluorescent light, but not under other, would make an interesting research problem, now that flicker index permits control of one of the variables. It is not inconceivable that our subjective knowledge of color might be increased thereby.

This writer disagrees with the opinion several times expressed in Washington to the effect that "at last strobe and flicker effects have been laid to rest," but believes, stead, that "at last strobe and flicker effects are opened up for real study in which results can be given in numbers instead of in rumors."

ARTHUR A. EASTMAN and JOHN H. CAMPBELL[7]: The authors wish to thank those persons who have expressed their interest in this paper by preparing discussions. They have pointed out certain difficulties and limitations of which we were not unaware, and have offered helpful criticism.

It is encouraging to note from Mr. Beggs' discussion that others in the industry have studied the problem and have some to the conclusion that flicker and stroboscopic effects are often over-emphasized. Also, we are pleased that our work coincides so closely with that mentioned by Mr. Beggs.

We agree with Dr. Fry that the wave form would change from the center of a lamp to the end, and that the effective frequency would also change because of the changing secondary maxima and minima. However, since we are primarily interested in the maximum effect of the flicker, the wave form at the end of the lamp should be the one to which the rating is applied when direct flicker is observed.

When the stroboscopic effect is to be considered, the overall wave forms as shown in Fig. 2 are of greater importance. We recognize that the flicker index does not take into account changes in frequency. When different lamps and circuits are compared they should be compared at the same frequency.

Dr. Simonson suggests that investigations should be carried out with various brightnesses. We would like very much to carry on further research into the fundamental relationships between wave form, brightness and frequency. It would be an interesting project, but we are unable to take the time at present.

We believe Professor Strong's suggestion for evaluating the stroboscopic effect has a great deal of merit. Again, lack of time prevents us from pursuing the investigation. We believe any results obtained by his proposed method would correlate nicely with our proposed index.

Mr. McCulloch will see from this discussion that the proposed flicker index is not the whole answer to the problem of flicker and stroboscopic effects. We do feel though, that the flicker index has a practical value in comparing lamps and circuits as we have shown. Its value could be increased by further research which has been suggested. There are many misconceptions regarding the relative merits of various circuits and ballasts as so aptly pointed out in Mr. McCulloch's discussion. One of the aims of this paper is to allay some of the confusion and encourage freedom of circuit selection from the standpoint of lamp flicker.

[6]Consulting Engineer, Shippensburg, Pa.

[7]Authors.

Lighting a Specialty Shop

LIGHTING OBJECTIVE: To illuminate a small store attractively and uniquely for the neighborhood.

Installation at the Nora Day Shop, Inc., 230 East Capitol Street, Jackson, Mississippi.

General Information: This area measures 44′ x 19′ 3″ x 13′. Surface characteristics are as follows:

Ceiling	aluminum louvers	65% RF
Sidewalls	blue-gray	50% RF
Floor	light green	40% RF
Display cases	blond wood	60% RF

Installation: Sixty 40-watt standard warm white fluorescent lamps (Garcy 8000-48-H strip) are mounted 2½ feet apart above a grid of aluminum louvers (Kawneer Alumigrid). The louver bottoms are 10′ 6″ above the floor. General illumination after 4000 hours operation measured 40 footcandles. R-40 reflector floodlamps mounted above the louvers over the display cases provide an additional 100 footcandles on the counters. Four spot lights are suspended below the ceiling for illuminating the manikins. Show cases are illuminated by deluxe warm white lamps.

Sidewall brightness is about 25 footlamberts; ceiling, 8 footlamberts.

Lighting designed by A. H. Walters, Mississippi Power and Light Company; installed by W. R. Crockett, Power Electric Company.

Lighting data submitted by A. H. Walters, Mississippi Power and Light Company, Jackson, Mississippi as an illustration of good lighting practice and to aid in the design of similar installations.

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Noise in Gaseous Discharge Lamps

By J. WARREN CULP

This paper describes an investigation of the noise behavior of fluorescent lamps. It is intended to cover several types of noise commonly encountered in the hot-cathode lamp with regard to the characteristics of noise and the associated phenomena in the discharge. Noise generation is interpreted in terms of changes in the space-charge distribution.

SOURCES of radio and television interference generally fall into one of two classes: oscillators and gaseous discharges. Oscillator-type sources include diathermy machines, television receivers themselves, and an occasional incandescent lamp which produces interference at television frequencies due to resonance in the filament structure.[1] Gaseous discharge noise sources comprise two groups: (1) the disruptive spark discharge, such as atmospheric lightning and sparks in the commutators of electric motors; and (2) the sustained discharge, as found in neon signs and fluorescent lamps.

Fluorescent lamps as noise sources are of special interest to the illuminating engineer because of their frequent use near radios and because of the possibility of controlling their radiation to the receiver. Radiation from the electrical wiring of the lamp can be effectively eliminated by well known methods.[2, 3] Noise radiation from the fluorescent tube itself cannot be prevented so easily, since the ionized gas acts as a transmitting antenna. Numerous investigators have looked into the question of noise generation in various gaseous discharge devices,[4] but not much has been published about noise in alternating-current discharges and specifically in fluorescent lamps. This paper is intended as a progress report on a study of the fundamental mechanisms of noise generation in fluorescent lamps.

The first part of the paper will deal mostly with observations, and the second part will consider interpretations of the phenomena with regard to noise. The term "noise" is to be used in its broadest sense, implying radio interference, audible noise from a loudspeaker, and transients in oscillograms, as the occasion arises.

PART I. *Noise Manifestations*

Let us consider several of the common types of noise which are generated by fluorescent lamps, paying attention mainly to the ways in which the noise manifests itself and to the characteristics of the discharge which seem to be associated with noise production. A brief examination of the equipment and its uses will serve as an introduction to these phenomena.

Apparatus and Applications

Most of the observations were made with 20-watt T12 lamps which were standard except for the omission of phosphor coating. These lamps have oxide-coated coiled-coil filaments and contain argon at 3 mm pressure saturated with mercury vapor. Power-line voltage at 60 cps was adjustable with a variable autotransformer, and a series resistor of about 150 ohms limited the lamp current, usually to 350 milliamperes. A resistive ballast was chosen instead of an inductive ballast for the sake of flexibility in the circuitry. A tuned communications receiver was sometimes useful in detecting the noise at radio frequencies, and could also be used for a rough determination of the frequency spectrum of such noise. Another useful receiver was one which was sensitive to all frequencies between a few hundred cps and 2 Mc/sec. The output of this receiver was thus a composite picture of all noise within its range and was displayed on the screen of a cathode ray oscilloscope. Fig. 1 shows the trace produced by a fluorescent lamp near the

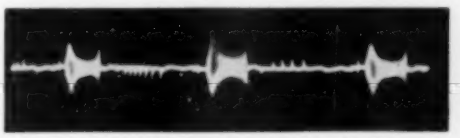

Figure 1. Noise oscillogram for one cycle of a fluorescent lamp.

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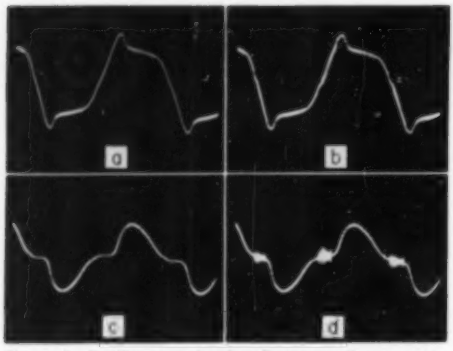


Figure 2. Oscillograms showing fluorescent lamp parameters as functions of time.

a. **Waveform of voltage across the lamp.**
b. **Composite trace produced by adding an amplified noise signal to the voltage signal.**
c. **Waveform of current through the lamp (signal represents *iR* drop across the series resistor).**
d. **Composite trace of noise signal added to the current signal.**

receiver antenna. Two forms of noise are visible: a series of low-frequency pulses and a pulse of "grass" noise occurring at various locations in the cycle. Since the photograph shows an overlaying of several dozen scope traces representing successive lamp cycles, it is evident that the lamp goes through essentially the same noise ritual on each cycle, with almost exact duplication in the case of the low-frequency pulses. A radio receiver tuned to a frequency in the broadcast band responds chiefly to the grassy pulses. Each pulse causes a thump in the loudspeaker, and the overall effect is that of a buzz with a 120-cps fundamental frequency.

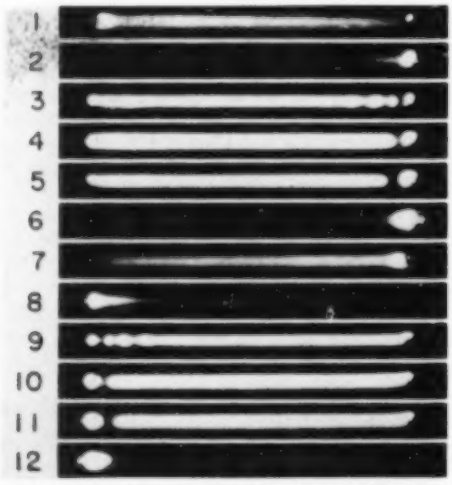


Figure 3. The lamp as seen through the rotating-disk stroboscope at a number of points throughout a complete cycle. The right-hand filament acts as cathode in 1 to 6, and the left-hand one in 7 to 12.

In Figs. 2a and 2c the total waveforms of voltage across the lamp and current through the lamp are plotted. If the signal which produces 2a is mixed with the output of the receiver used to detect the radiated noise, the trace shown in Fig. 2b is obtained. The composite waveform for current which is shown in Fig. 2d is obtained in a similar manner. It should be noted that the low-frequency noise pulses have been electrically filtered out of the noise signal. Noise starts shortly after the zero point of the cycle and ceases generally before the "breakdown" peak in the voltage curve. On the current curve, the noise occupies the low plateau at the start of the cycle. A small pulse can also be seen at the end of the half-cycle.

A direct-viewing stroboscope is valuable in studying the periodic changes that take place in the discharge tube itself, and in relating these to the oscillographic observations. Two types of stroboscope have been used. One is a rotating disk which has thin slots cut in the radial direction and is positioned between the lamp and the observer. If two slots are used and the disk is driven by an 1800-rpm motor, one slot passes before the eye each 60th second. When a glowing lamp which is dimming and brightening at a 60-cps rate is viewed through the rotating disk, stopped motion results. The apparatus is so constructed that the discharge may be "stopped" at any chosen point in the cycle. Photographs of an uncoated lamp as seen through the disk are shown in Fig. 3 for a number of points throughout the cycle. The slit of the disk moves vertically across the field of view in each case. These photographs are time exposures, or really multiple exposures of the same view, as repeated many times over successive lamp cycles. Here is another illustration that the lamp does almost exactly the same thing every time a given point in the cycle is reached.

A second type of stroboscope utilizes a rotating mirror and gives the effect of holding a narrow discharge tube with its axis vertical, and moving the tube horizontally at a very high speed. The image one sees is similar to a picture made up of a series of rotating-disk photographs placed side by side. Exceedingly high time-resolution can be achieved with the rotating mirror by masking the discharge tube so that only a thin longitudinal sliver of it is in sight. A photograph of the lamp as seen with the rotating mirror is shown in Fig. 4. The width

of the picture represents a time lapse of 0.002 second, or one-eighth of a single lamp cycle. Beginning at the bottom, one clearly distinguishes the bright glow about the cathode, above it the Faraday dark space, then the positive column with typical striations (horizontal streaks) moving toward the cathode, and finally the bright, pulsating anode glow at the top. Toward the right the striations are washing out; the rest of the half-cycle appears much the same, without horizontal striations.

It is sometimes convenient to observe some parameter such as lamp voltage at the same time one views the "stopped" discharge. Proper location of an oscilloscope makes this a simple matter. A rotating-mirror photograph of the anode end of a lamp is presented in Fig. 5, with an expanded oscillogram of lamp voltage above. The mirror provides a time base or sweep for the oscilloscope, and phase and synchronism are achieved automatically. The fluctuations in the oscillogram correspond to the sawteeth atop the voltage curve of Fig. 2.

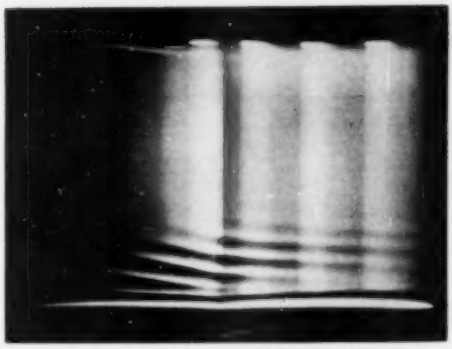


Figure 4. The lamp as seen with the rotating-mirror stroboscope over a period of 2 milliseconds at the beginning of a cycle. The lamp is in a vertical position, and the cathode is at the bottom during the time shown. Time increases toward the right.

Noise Types

With these phenomena in mind, we are ready to assign names to the several types of noise and discuss them individually. The grassy pulse at the beginning of the lamp cycle will be called *reignition noise*, because it occurs when the arc begins to rebuild after current reversal. A second type of noise, which has not been mentioned, is *hollow-cathode noise*. It has already been noted that the low-frequency pulses in the middle of the half-cycle bear a relation to the anode glow, and these pulses will be called *anode noise*. Finally, the noise which is generated during operation of the lamp starting circuit, although perhaps a combination of the above types, will be dealt with separately under the name *starting noise*.

Reignition Noise

The most interesting type of noise, from a practical, as well as a technical point of view, is the reignition type that comes in a pulse at the beginning of each half-cycle. There are two reasons for this. First, the reignition noise in hot-cathode lamps is usually louder than other types when heard in a radio loudspeaker and is thus more conspicuous. Second, the mechanism which accounts for reignition noise is not easily observed or explained, so that a great deal of information must be gained during the course of its study.

A crude frequency spectrum analysis may be made by tuning a receiver over the range from 540 kc/sec to 31 Mc/sec and judging the relative loudness of noise coming from the speaker. Such a check shows that the reignition noise is chiefly concentrated in the range below 2 Mc/sec and possibly is loudest around 1 Mc, directly in the middle of the broadcast band. Other than this there are no particular prominences or valleys in the spectrum. When account is taken of the seeming randomness of radio-frequency noise within each pulse in the oscillogram of Fig. 1, a conclusion would be that

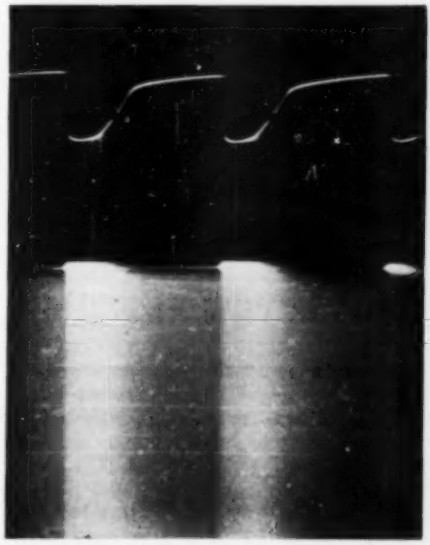


Figure 5. Rotating-mirror view of the lamp near the middle of a half-cycle, showing the pulsating anode glow. The cathode is below, off the picture. At top is an oscillogram of lamp voltage. Elapsed time is one millisecond. Time increases toward the right.

the reignition noise consists of either a random series of rapid pulses or a frequency-modulated oscillation. In the latter case, the frequency of the oscillatory wave must sweep across the entire broadcast band of a receiver, so that no matter to what frequency the receiver is tuned, its circuit will respond to the noise. Furthermore, this broad sweep must be accomplished during the life of each single reignition pulse of noise to give the observed overall effect of a 120-cycle buzz.

There is evidence in favor of a conclusion that the reignition noise is simply an oscillating wave whose frequency changes sporadically throughout the duration of the pulse. By means of a special circuit, a lamp operating on direct current was put into a condition closely resembling that of the a-c operated lamp in the noisy portion of its cycle. In this experiment, the d-c lamp did indeed produce noise, which was confined to rather narrow frequency bands. A slight increase in discharge current caused an increase in the frequency. It was suspected that the frequency would have had a line spectrum instead of a band spectrum were it not for a minute fluctuation in the current, which seemed to be causing a modulation or spread of the frequency.

Obviously, a direct approach to this problem is to take the noise oscillogram of Fig. 1 and blow it up to such an extent that the individual pulses of the radio-frequency wave can be viewed. This was done with the aid of a circuit which turned on the cathode ray beam for a period of 250 microseconds at any chosen point in the lamp cycle. Any noise appearing in the signal during that period was spread across the face of the cathode ray tube. The confusion usually resulting from the overlapping of successive traces of the beam was eliminated by switching the beam on only once in every ten lamp cycles. Thus six pictures per second flashed on the screen, and the characteristics of any one of them could be distinguished. In practice, the duration of the sweep was 50 microseconds, so that the beam made five sweeps during the "on" period. These five traces were caused to appear one above the other by using a vertical as well as a horizontal scan. Since the purpose of this work is to find the mechanism of noise generation in the lamp, the noise which is present but invisible in the voltage and current traces of Figs. 2a and 2c is of much greater interest than the radiated noise picked up by a receiver. The oscillograms in Fig. 6 are the result of applying this technique to the signal representing current through the lamp. Each photograph shows a small portion of the whole reignition noise pulse; one was taken near the beginning of the pulse, and the other shows the abrupt end of the pulse. While these photographs leave some doubt as to whether the noise may be described as a frequency-modulated oscillation, they certainly prove that the noise is not always random. Measurements from the oscillograms indicate that the fundamental frequency is in the neighborhood of 200 kc/sec, well below the broadcast band. One is therefore led to believe that the tuned receiver responds to higher harmonics of the fundamental noise frequency.

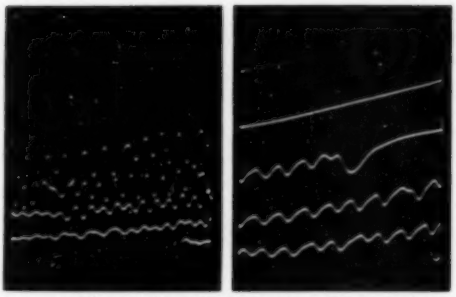


Figure 6. Expanded oscillograms of current through the lamp, showing reignition noise in the current signal just after the beginning of a cycle. Time increases toward the right, with a slower scan from bottom to top.

Before any use can be made of information about the nature of reignition noise, the source of noise in the lamp must be located. An attempt to find it with an exploring antenna or coil is not too fruitful, because noise generated at one place in the lamp is radiated by the whole discharge acting as a transmitting antenna. However, this experiment does tend to localize the source of any given noise pulse at the filament which acts as cathode at the time the pulse is emitted. A magnet held near one filament causes some changes in the noise pulse radiated when that filament is cathode, while the noise on the other half-cycle is unaffected. An auxiliary heating current through one filament gives a similar effect. In fact, on occasion the noise is almost completely quenched by these methods. Unfortunately the experiment is seldom reproducible at will. A more conclusive demonstration of the source of noise can be made by constructing a short lamp with only an inch between the two filaments. The discharge then consists of the usual cathode and anode structures but has no positive column. There is no essential difference between oscillograms of noise from the short lamp and noise from a standard lamp. Since the other experiments showed that the anode plays no part in generating reignition noise, it is concluded that the cathode is the true source of noise. Moreover, it has been seen that the noisy period occurs during the building up of the discharge at the beginning of the cycle.

Some views of the discharge at different points in the lamp cycle were shown in Fig. 3. A more intensive examination of the discharge at the beginning of the cycle throws some light on the mechanisms which are in operation and which might be associated with reignition noise. In Fig. 7 are shown twelve closely spaced steps in the process of extinction of the discharge at the end of a cycle and rebuilding of the structure as current begins to flow in the opposite direction. There is a brief time during which none of the typical parts of a discharge is present. This is the afterglow period, and the faint light which fills the tube is yellowish and not the usual blue of a mercury-argon discharge. There is some evidence that the light of the afterglow consists of the ordinary mercury spectrum with intensification of the yellow 5769, 5790A lines. Such an effect might be accounted for by two-body collisions between metastable mercury atoms, from which one atom emerges with all the internal energy. This is just the right amount of energy to result in the emission of the yellow lines. Following the afterglow period, the blue cathode glow fades in. A dark space is clearly discernible between the glow and the incandescent filament. The cathode glow becomes more intense and finally moves in and surrounds the filament. Meanwhile the afterglow fades out, and a columnar glow makes an appearance along the axis of the tube. Finally a portion of the column extinguishes and leaves in its place the Faraday dark space.

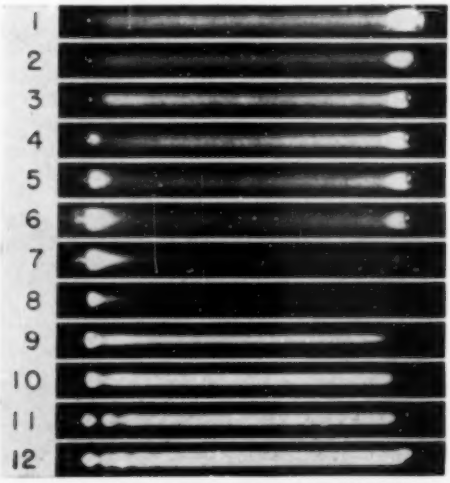


Figure 7. The lamp as seen through the rotating disk at several successive points in a small portion of the cycle. In 1 and 2, the cathode glow (right) is extinguishing. Note the afterglow in 3, followed by the appearance of a new cathode glow in 4 (left) as the current reverses.

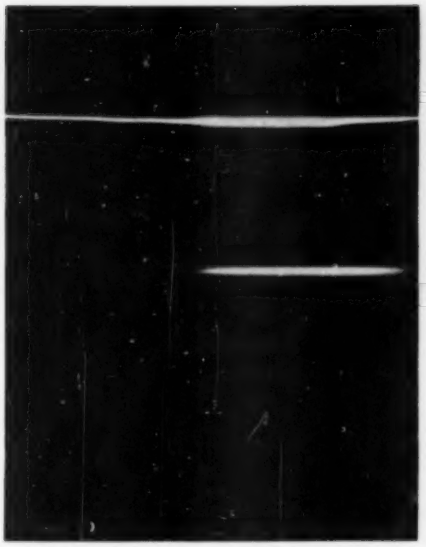


Figure 8. Rotating-mirror view of the lamp at the beginning of a cycle. The anode is below, off the picture. Only the newly forming cathode glow is visible (center). At the top is an oscillogram of reignition noise. Time increases toward the right.

Several other dark spaces form in the column head and make the striations which were seen in Fig. 4. Discrepancies between the rotating-disk photographs of Fig. 7 and the rotating-mirror photograph of Fig. 4 are the result of longer exposure times for the former.

It is important to note that the reignition noise pulse begins at the same time the cathode glow is approaching and joining the filament. This is shown in Fig. 8. The very fine streak across the center of the picture is the incandescent filament as seen in the rotating mirror. Halfway across, the cathode glow appears and quickly becomes attached to the front of the filament. (The apparent fading of the glow at the extreme right is due to the optical arrangement.) The noise oscillogram at the top was made by the method used in Fig. 5. It shows a broadening, which represents the beginning of the reignition noise pulse, at the same time the cathode glow forms.

Hollow-Cathode Noise

One type of noise which appears in many cases is known as hollow-cathode noise. It is more likely to occur in aged lamps, although new lamps sometimes show it. This noise results from the formation of the cathode spot at a point on the coiled-coil filament where some of the oxide coating has

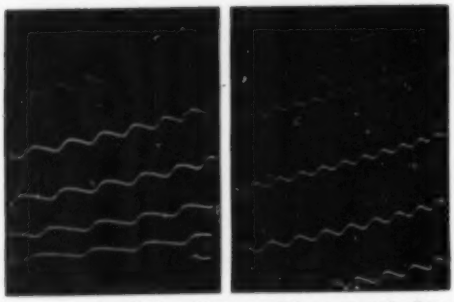


Figure 9. Expanded oscillograms of lamp current, showing hollow-cathode noise in the current signal. Time increases toward the right, with a slower scan from bottom to top.

burned away and left a tiny hollowed-out cavity in the minor helix. When that happens, a noise oscillogram similar to Fig. 1 shows one or more pulses of radio-frequency noise located almost anywhere in the cycle. The pulses, unlike those of reignition noise, are smooth in appearance; there is nothing random in their nature excepting possibly their location in the cycle. The oscillograms in Fig. 9 are attributed to hollow-cathode noise. One photograph shows a continuation of the trace in the other. The frequency, as determined from these photographs, changed smoothly from 75 to 300 kc/sec over a period of 350 microseconds. Hollow-cathode noise, like reignition noise, causes a pronounced buzz in the loudspeaker of a tuned receiver.

The cathode spot of the discharge can be studied by means of a microscope in conjunction with the rotating-disk stroboscope. When hollow-cathode noise is present, at a certain time in the cycle a tiny glow appears suddenly inside the hollow of the minor helix. A millisecond or so later it disappears just as suddenly. Other than this, there is no observed peculiarity of the discharge associated with this type of noise. Sometimes two separate pulses are found in the noise oscillogram, and it is believed that one of them comes with the appearance, and one with the disappearance, of the glow.

It is interesting to note that hollow-cathode noise can also be produced by operating one of the lamps on direct current. When the minor helix of the filament has a hollow place and the cathode spot of the arc forms next to that point, a slow increase in the lamp current to a certain value results in the sudden formation of a glow inside the helix cavity. Simultaneously there is a pop in the receiver, and the lamp voltage drops by a small amount. If the current is then decreased, the original state of the arc is suddenly resumed at a slightly lower current, to the accompaniment of another pop. The current can be made to increase and decrease at a 60-cps rate, and the cathode spot follows the same procedure at this rate. The noise, of course, then sounds like a buzz.

Anode Noise

The noise which is associated with the anode glow is so low in frequency that it has negligible effect on a standard tuned receiver. The output of a wideband receiver (Fig. 1) shows that the low-frequency noise pulses have a repetition rate of 500 to several thousand cycles per second. It can be seen from Fig. 10 that when the noise signal is added to the curve representing voltage across the lamp, each anode pulse matches one of the teeth on the voltage curve. The rotating mirror photograph of Fig. 5 shows, in turn, that the teeth on the voltage curve match the visible pulsations in the anode glow of the discharge. In addition, a magnet held near one filament has a pronounced effect on both the noise pulses and the voltage teeth which are present on the half-cycle when that filament is anode. Usually a magnet causes the pulses to shift their position in the cycle and increase in number, although sometimes they completely disappear as the magnet approaches the tube. These observations leave no doubt that the anode noise is indeed generated in the anode region of the discharge.

The low-frequency noise which anode pulsations introduce into the electrical circuit by way of the lamp current is visible in the left-hand current curve of Fig. 2. The teeth atop the current curve are simply an inversion of the teeth on the voltage curve, which are shown magnified in Fig. 5, since the current is directly proportional to the difference between the smooth supply voltage and the toothed lamp voltage when a resistive ballast is used.

Much attention has been given by a number of investigators to the pulsations which occur at the

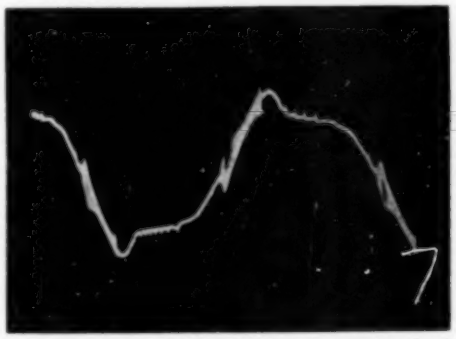


Figure 10. Lamp voltage oscillogram with noise signal added, showing the anode pulses.

anode and affect the entire discharge.[5, 6, 7] In Figs. 4 and 5 it is clear that the whole positive column changes its light output periodically with the flashing anode glow, as indicated by the vertical stripes. This effect is to be expected, because the light output is governed by the current, which fluctuates along with the anode glow. The voltage oscillogram in Fig. 5, which is identical to an inverted current oscillogram, might easily be mistaken for an inverted light intensity curve when it is compared with the light from the discharge shown below it. There is no evidence here in favor of one current theory that the vertical bars represent striations moving at phenomenally high speed from cathode to anode.

Starting Noise

When the starting circuit of a lamp is in operation, an arc forms in shunt across the filament. Although the filament-shunting arc is not a self-sustained one, since its cathode is heated by external means, still it has the necessary characteristics for the generation of noise. Oscillograms show that the starting noise resembles reignition noise of the ordinary arc. Noise of the anode type is probably also present, since a stroboscope shows that a pulsating anode glow exists. In view of the fact that the starting noise has the same causes and characteristics as other types of noise, further study would not be profitable.

Part II. *Noise Origin*

It should now be possible to discuss some of the fundamental processes in the discharge that recur on each cycle and have to do with the generation of noise. It has been shown that the anode and cathode regions alone are involved with a few common types of noise. The noise was observed and the discharge was observed. There remains the necessity of tying the two types of observations together. First, the problem will be viewed in terms of the electromagnetic theory of radiation, and next the noisy d-c glow-to-arc transition will be considered to see what bearing it has upon noise in a-c fluorescent lamps.

Theory

Some understanding of the mechanisms in the discharge which give rise to noise radiation can be gained from a brief examination of Maxwell's wave equation,

$$\nabla^2 E - \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = 4\pi\left(\frac{1}{c^2}\frac{\partial i}{\partial t} + \nabla\rho\right)$$

where E is the electric field, i the current density, ρ the space-charge density, and c the velocity of light. In the case of the fluorescent lamp, it is difficult to set up suitable boundary conditions for the solution of this equation, since very little is known about current and space-charge densities in the alternating-current arc discharge. This does not imply that the wave equation is useless, however.

Since noise at radio frequencies is observed, the fluorescent lamp must radiate electromagnetic energy at these frequencies. This means that there is an electric field E that varies in time. Maxwell's equation shows that such a variation in E can arise from a time-varying space-charge density. This implies, of course, a current-density variation since current and space-charge are related by the equation of conservation of charge. However, at radio frequencies, the term in which i appears is small compared to the term involving ρ.

Thus any phenomenon involving rapid changes in the space-charge distribution will generate noise. Such a change is demonstrated in two dimensions in the model shown in Fig. 11. A change of this

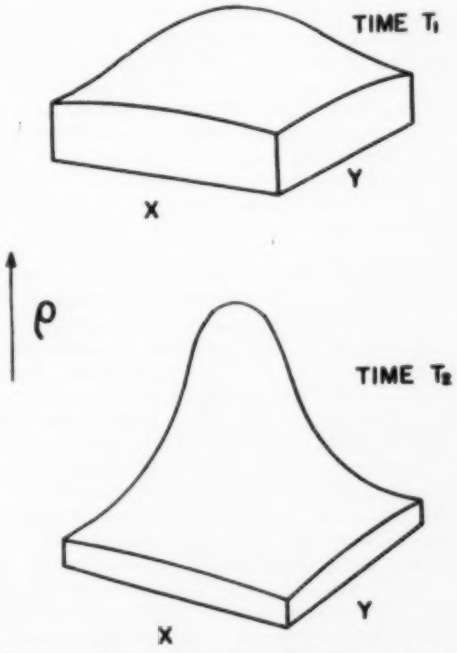


Figure 11. Model of space-charge density ρ as plotted over an area XY at two different times.

type occurs at the cathode in the glow-arc transition, as will now be shown.

The Glow-Arc Transition

It is well known that if a tube is operated with a glow discharge on direct current, and the current is gradually increased, the negative glow will spread over a larger and larger area of the cathode until the whole cathode is covered, and local heating will occur. If the resistive ballast in the circuit is not large, further increase of current results in a sudden concentration of the cathode glow about a single hot spot. A simultaneous collapse of tube voltage is noted, perhaps from 200 volts down to 50 volts. The new state of the discharge is, of course, the arc. At the time of the almost instantaneous transition from glow to arc, a receiver registers a sharp noise pop. It would be well to consider the mechanism underlying this noise before advancing to the less accessible circumstances of reignition noise.

An attempt to plot usable voltage or space-charge distributions would, at present, be largely speculative. Fortunately, the only question that must be answered is whether the space-charge distribution makes a rapid change during the glow-arc transition. Obviously it does, for the ion sheath that surrounds the whole cathode in the glow must contract quickly to center about the hot spot. Moreover, the current density changes from a low value, when it is spread uniformly over the cathode, to a figure probably hundreds of times as great at the hot spot. These changes are believed to be sufficient to account for the noise.

Actually the foregoing discussion is somewhat superficial. With a small resistance as ballast in the lamp circuit, there is certain to be a large change in total current during the transition, because of the diagonal load line on the voltage-current characteristic. This difficulty was overcome by operating the direct-current discharge in a circuit which rigidly regulated the lamp current. The value of this current could be adjusted with a potentiometer, and the load line was essentially vertical (*i.e.*, a change in lamp voltage did not affect the current). With this circuit, the transition is found to be reversible, although the arc-to-glow transition occurs at a lower value of current than the glow-to-arc transition. A typical characteristic which would appear on an oscilloscope screen is shown in Fig. 12; the tube in this case was an 8-watt T8 germicidal lamp. It is seen that the transition is accomplished so rapidly that a portion of the characteristic is invisible. Even so, it was necessary to turn up the current control rapidly to produce noise in a tuned receiver. An examination of the discharge shows why this is true.

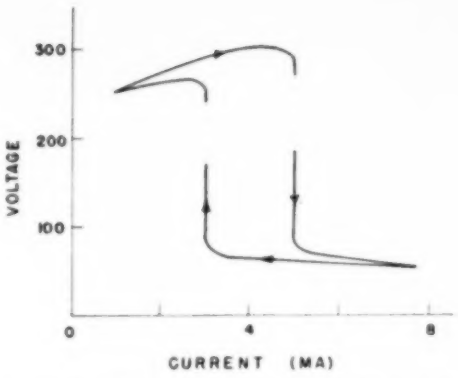


Figure 12. Voltage-current characteristic for a lamp operated on regulated direct current.

The fast transition through the invisible portion of the characteristic alone does not end in the formation of a hot spot on the cathode, but results only in a hollow-cathode glow inside the major helix of the filament. This is a more economical form of negative glow and thus the glow discharge can operate at a lower voltage. The arc hot spot is formed during the vertical trace which is shown at the right in Fig. 12. In this case, it forms rather slowly and hence noiselessly. Rapid formation of the hot spot gives a noise pulse for reasons which have been outlined.

Reignition in the Alternating-Current Arc

The noisy glow-arc transition is a convenient starting point from which an explanation of reignition noise may be developed. First some basic similarities and differences in the two types of discharge must be outlined. The d-c discharge is strictly self-maintaining: the cathode is hot at any given time because the discharge has been heating it for the past several seconds, and since ions are bombarding it, it will continue to be hot. At the time of reignition in the a-c arc, on the other hand, the cathode is hot by virtue of its retention of heat from the previous cycle; the discharge at this time is too weak to contribute any appreciable energy to heating of the cathode. Something similar may be said of space-charge. The maintenance of a favorable space charge distribution in the d-c discharge is a continuous process of depletion and replenishment, and the glow-arc transition merely calls for conversion to a different mechanism for the maintenance of space charge in a new distribution. The a-c dis-

charge, however, inherits very little space charge from the previous cycle. Almost the only thing that characterizes the space in the gas just before reignition is that it is filled with metastable mercury atoms, as shown in the discussion of the afterglow. Metastable atoms are easier to ionize than unexcited atoms, and they probably play an important role in reignition. It is clear then that there is no such thing as a glow discharge in the reignition phase of the a-c arc.

The glow-arc transition and the a-c reignition phenomenon have one thing in common. The space-charge and current-density distributions about the cathode are in a state of rapid alteration. This change was found to account for the noise pulse produced in the transition. It must also account for reignition noise. It would be valuable to know the exact nature of the change in space-charge distribution which gives rise to noise in the a-c arc. Thus far, this problem has not been approached directly. However, there is circumstantial evidence that gives something of an overall picture of the situation. It has been seen that a sharp-fronted glow materializes in the space before the cathode at the time of reignition. Prior to this time the emission appears to have been purely thermionic (there is a small but measurable current before the formation of the glow). About the time that the glow collides with the cathode, the current shifts to a higher level which is maintained until the so-called breakdown peak of voltage is reached. The shift in current occurs with approximately 10 volts across the lamp, and there are indications that the cathode region alone supports almost the entire voltage drop. It is believed that the shift in current is caused by the onset of a new emission mechanism, namely emission by ion bombardment. At this time, the noise begins. It may be tentatively concluded that the noise starts at the time an ion sheath forms in front of the cathode, and that the rapid building up of ionic space charge is the cause of noise. The reason for the oscillatory nature of the noise has not been established.

The Hollow-Cathode Discharge

A discharge having a hollow cathode can operate more efficiently when a part of the negative glow forms inside the cavity. A necessary condition for this glow structure is that the cathode dark space must be thin enough to leave room for a certain amount of glow; otherwise the whole cavity must be filled with dark space. The exact relationship between dark space thickness and lamp current is not known. It is certainly known that the glow discharge has a relatively thick space, and it is inferred from the hollow-cathode effect in the glow discharge that the thickness decreases with increasing current until it finally becomes possible to include both dark space and glow inside the major helix of the filament. That process is duplicated in the arc discharge, except that the dark space is much thinner, and the glow forms inside the minor helix because the effective cathode is confined to a small area. The sudden materialization of a negative glow inside the cavity implies the sudden building up of a positive ion sheath. Hence redistribution of space-charge density explains the hollow-cathode noise in the arc. The possibility of a frequency-modulated oscillation of space charge as it builds up or decays has not been explored, but some such effect may be expected to occur because of the nature of the noise.

The Pulsating Anode Glow

Anode noise is easily understood on the basis of changes in the space-charge distribution. Observations show that the anode glow starts as a small luminous region and spreads out rapidly, becoming larger and less well defined. Soon it disappears completely, leaving a dark space for a time. Then another glow appears on the anode and the process is repeated. It is obvious that changes must be going on simultaneously in the space charge at the anode. These changes are abrupt at the time of formation of each glow, and a noise pulse results.

A partial explanation of the pulsating anode glow is the following. Positive ions are repelled from the anode within a small region. The net space charge is negative because of the electrons which are flowing toward the anode. The space-charge distribution produces a small potential drop next to the electrode. The voltage drop soon becomes large enough so that electrons falling through it gain sufficient energy to ionize some atoms just outside the anode. This process is analogous to the formation of the negative glow and ion sheath in the reignition process. Since the new positive ions are slow in moving away, each of them neutralizes many electrons and the net space charge is immediately brought back to normal. The voltage drop partly collapses, and no further ionization can take place until the new ions have drifted away from the anode.

In direct-current discharges, the pulsations have been found to disappear at higher mercury pressures or at higher currents.[7] The reason for this is probably that the ions no longer drift far enough away from the anode to leave a large negative space charge, so that the anode potential drop never grows large enough to cause a sudden burst

of ionization. The pulsating anode glow tends to appear at sharp points or edges on the anode structure, where the field is high. It sometimes alternates between two places on the anode. This fact suggests that local heating or surface conditioning may play some part, although there is a possibility that two effective anodes on one filament are operating independently, in parallel.

Summary

It has been shown that noise which originates in a fluorescent lamp because of reignition, a hollow cathode, anode glow pulsations, or the starting glow may be interpreted as rapid changes in the space-charge distribution.

The author is indebted to Mr. William Hoenig, who designed several of the special circuits and carried out many of the experiments which have been described in this paper.

References

1. Fink, D. G.: "TV Interference from Incandescent Lamps," *Electronics*, Vol. 22, p. 132 (December 1949).

2. Shorey, L. F. and Gray, S. M.: "A Preliminary Study of Radio Interference as Caused by Fluorescent Lamps in the Home," ILLUMINATING ENGINEERING, Vol. XLII, p. 365 (March 1947).

3. Diallist: "Interference from Fluorescent Tubes," *Wireless World*, Vol. 56, p. 93 (March 1950).

4. For an excellent survey, see Cobine, J. D. and Gallagher, C. J.: "Noise and Oscillations in Hot Cathode Arcs," *Journal of the Franklin Institute*, Vol. 243, p. 41 (January 1947).

5. Papp, W.: "On the Influence of the Anode on the Stability of the Homogeneous Column Plasma in Argon," *Physikalische Zeitschrift*, Vol. 34, p. 756 (1933).

6. Loh, H. Y. and Dicke, G. H.: "Fluctuations in Gas Discharges," *Journal of the Optical Society of America*, Vol. 37, p. 837 (October 1947).

7. Steele, H.: "Fast and Slow Moving Striations in a Mixture of Mercury and Inert Gases," Abstracts of Papers at the Conference on Gaseous Electronics, p. F7 (November 1949).

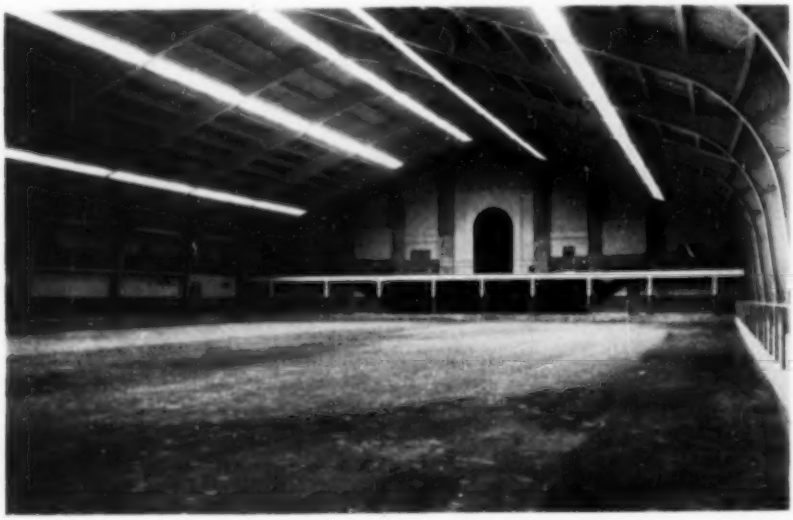
Truss-Mounted Reflectors Used in Field House

This large field house, at the Lawrenceville School, Lawrenceville, N. J., is lighted by five bands of units, continuous except where interrupted by the main steel trusses. The play area, one end of which is shown in the photograph, is 134 ft 4 in wide by 313 ft 4 in long and 40 ft high from the floor to the high point of the roof truss. The lighting units are omitted in the end bays, so that each band is approximately 280 feet long. Each band consists of two parallel rows of open-end porcelain enamelled steel reflectors, without apertures, and is equipped with two 96-inch T-12 slimline lamps on five-inch centers with spring holders.

The reflectors are mounted on rigid steel supports, centrally under the steel roof purlins. The reflectors in each band are placed tangent to the arc of the roof truss so that the axes of the two bands on both sides of the center are directed slightly toward the center.

The illumination averages 35 to 40 footcandles in the main body of the play area but falls off sharply around the perimeter, because of the off-vertical mounting of the reflectors in the outer bands. There is a total of 300 reflector units with an installed capacity of 55 kw.

Architects: W. T. Karcher and Livingstone Smith, Philadelphia; Consulting Engineers: Moody and Hutchison, Philadelphia; R. A. Wolf in charge of lighting design.



Recent Progress In the Art of Lighting

Report of I.E.S. Committee on Progress—1950-51

ALSTON RODGERS, *Chairman*

IN REPORTING on lighting progress, one significant indication can be gleaned from an analysis of the U. S. Department of Commerce Reports on the sale of electric lamps in the United States. The first two sections of Figure 1 present an overall summary of these reports, in round figures, showing the increase in annual lamp demand over the last five years. In 1945, at the end of World War II, many of us thought we had arrived at some sort of peak in demand for light. Yet, last year we used about 25 per cent more lamps, representing 50 per cent more dollars, than in 1945.

A further analysis of the reports reveals some other interesting facts. Demand for fluorescent lamps increased about 115 per cent over the five-year period, while quantities of all other lamps advanced only about 20 per cent. In spite of the fact that lamp prices increased only a few per cent, dollar volume of fluorescent lamps increased about 185 per cent. This indicates increased purchases of the larger, more efficient fluorescent lamp types, several of which, such as the 96-inch T-12 lamp, were introduced during the period. Today, about 50 per cent as many dollars' worth of fluorescent lamps are sold as the dollar volume of all other types—quite a record for a light source only 12 years old.

In the third section of Figure 1 the lumen-hours represented by the lamps sold in 1945 and 1950 have been estimated from the reports. An increase of about 100 per cent in the use of light is indicated. This is due largely to the increased sales, efficiencies and lives of the newer light sources. By purchasing 25 per cent more lamps, costing 50 per cent more dollars, the American public has received 100 per cent more in lighting value. The appetite for lighting in this country has about doubled in five years.

Certainly these facts are a tribute to the lamp and lighting industry. They emphasize the importance of new developments.

As additional evidence, one lamp manufacturer states that its sales of high intensity mercury lamps for industrial, street and flood lighting have about doubled in the past year. Figures from another lamp maker show that lamps not listed ten years ago were responsible for nearly 45 per cent of its business last year, and 13 per cent of the business was due to lamps placed on the market only within the past 30 months.

Light Sources and Accessories

Because of material limitations made necessary by our defense mobilization program, lamp manufacturers have concentrated on making the best use of materials and manpower to produce the quantities of lamps needed today. Consequently, few new types of lamps have been introduced during the year with the exception of new lamps for the military or to aid in lighting for production.

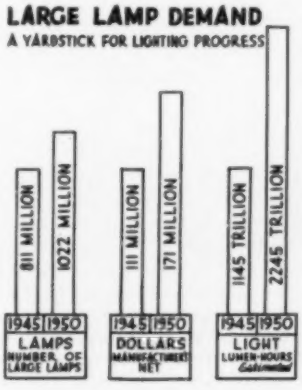


Figure 1. Large lamp demand.

Particularly in military circles, there has been renewed interest in compact-source high-pressure mercury lamps which do not require auxiliary cooling equipment, for possible application in small search lights, airport ceilometers and other such devices. One design of these short-gap mercury arcs is rated at 1000 watts and produces a source brightness of 250 candles per square millimeter or better. Another such lamp, of somewhat different form, is rated at 800 watts with a brightness in the order of 200 candles per square millimeter.

Among the hard glass, projector type lamps introduced this year are:

PAR-36, 24-28 volt military vehicle head lamp with a 100-watt driving beam filament and a 50-watt passing beam filament.

PAR-36 hand lantern lamp, for operation on a 6-volt hand lantern battery, with a clear lens to provide a concentrated beam of high candlepower.

PAR-38 side prong 150-watt, 120-volt mining equipment lamp. An unusual spring-mounted filament arrangement makes this an extremely rugged lamp for such rough and ready service.

The 200-watt PAR-56 locomotive headlight lamps, introduced a few years ago, have found a new application in the oscillating warning lights for locomotives. Some of the new trains are now equipped with six of these powerful lamps, two as headlights, two as locomotive warning signals and two as red warning signals at the rear of the train.

The 500-watt and 750-watt R-52 reflector lamps for high bay industrial lighting have gained rapid acceptance because they maintain illumination values very well, even in dirty atmospheres, with a minimum of maintenance. A similar industrial reflector lamp in an R-57 bulb rated at 800 watts and with a more concentrated lighting distribution, has been introduced by one manufacturer.

A report presented at the 1951 National Technical Conference of the Illuminating Engineering Society, Washington, D. C. Approved by the I.E.S. Council December 1951.

A line of 150-watt reflector lamps in R-38 hard glass blown bulbs in spot and flood types has been placed on the market. These are said to be interchangeable with the heavier PAR-38 lamps in all types of equipment.

One lamp manufacturer has announced that all its 100-watt rough service lamps have been reduced in size to the A-21 bulb. This makes possible the use of a 100-watt lamp in equipment designed for 60-watt lamps with a great increase in light output. These lamps are available in clear and inside-frosted bulbs for both standard and high-voltage service.

Small filament lamps have been introduced for testing photoflash camera synchronizers. One lamp, in a G-6 clear bulb with s.c. bayonet base, tests equipment designed for "midget" photoflash lamps. Another, with an S-14 clear bulb and medium screw base, tests larger photoflash units. Both types have a 3.8-volt, 0.30 ampere filament designed for a maximum of three flashlight cells.

At the 1950 I.E.S. National Technical Conference a new heating unit for electric ranges, in the form of a lamp bulb, was announced.[1] In a gold-plated R-44 bulb of Vycor glass, this new infrared cooking lamp contains a 500-watt filament and a 750-watt filament, each operating on 115 and 230 volts to match the heat settings of the standard electric stove. In use, a red Vycor plate set above the bulb furnishes the cooking surface and protects the lamp. It is stated that within two or three seconds after being turned on the lamp sends full heat through the plate and into the bottom of a cooking utensil, with the result that small amounts of food can be cooked about 30 per cent faster with the lamp than with the usual heating coil.

So-called "agitator" lamps, announced a few years ago, are reported to have found commercial applications in the novelty field. These unusual light sources are in the form of glass tubes or bulbs containing a mixture of mercury and a fluorescent phosphor with a little neon gas present in the bulb. When shaken violently they emit a faint light visible under completely dark conditions. Recent developments are said to have produced some increase in brightness. Applications reported are for fish lures, roller skate wheels, yo-yos and canes for the blind.

The electroluminescent plate, a new type of light source announced last year,[2] has received a good deal of publicity during the year and it has been the subject of considerable development work aimed toward getting this new surface light source out of the field of experimentation and into practical application.

Sometimes described as a luminous condenser, the electroluminescent plate, in its present form, consists of a panel of glass with an invisible coating which conducts electricity, a thin layer of phosphor suspended in a dielectric and a thin metallic backing. When the conducting surface of the glass and the metallic backing are connected into an alternating current circuit the device acts as a condenser and the phosphor emits light through the glass plate.

At the present stage of development, the brightness of the panels on standard 120-volt, 60-cycle circuits is of a very low order and effective only under dark-adapted conditions. However, light output is increased considerably at higher voltages or higher frequencies or both. Several phosphors have been developed to generate light in a limited number of colors. It is suggested that this new method of generating light soon may find practical application for such purposes as luminous clock and radio dials, wall switch plates, house numbers and small signs. Further development may some day place the electroluminescent plate among the sources of useful illumination.

Manufacturers of cold cathode fluorescent lamps report a number of new developments:

Life rating of the standard cold cathode type HP lamps has been increased from 15,000 hours to 25,000 hours independent of the number of lamp starts.

Cold cathode lamps are now being manufactured in standard lengths of 4 feet, 6 feet and 8 feet over all from end of socket to end of socket.

A simple push-pull socket for series operation of standard cold cathode lamps has been developed.

New ballasts for cold cathode lamps include a 200-milliampere ballast and a ballast to operate four 8-foot lamps.

A line of ballasts rated by the number of standard lamps which they operate at a given current has been placed on the market.

Cold cathode lamps in the form of a small grid have been designed for use as light sources in photo-enlargers. One type of such grid makes it possible to convert certain cameras for use as photo-enlargers.

Figure 2. Progress Committee Chairman, Alston Rogers, with some of the new equipment demonstrated at the 1951 I.E.S. National Technical Conference. Left, a new infrared brooder unit with built-in thermostat, for the farm. Center, street-lighting luminaire for building-front mounting. Right, new vapor-tight prismatic glass industrial lighting luminaire for indoor and outdoor use.

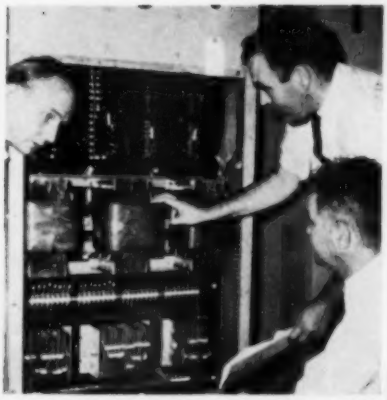


Figure 3a. A new high-frequency system uses small capacitors as ballasts to operate eighty-eight 96-inch T-8 slimline fluorescent lamps, providing nearly 3000 footcandles in an underground test room for research in plant growth by the U. S. Department of Agriculture at Beltsville, Md.[3] Conventional ballasts for this installation would have weighed about 1500 pounds. The tiny capacitors do the job with one-tenth the weight, one-twentieth the size and one-seventh the wattage loss. Figure 3b. One of the two convertors used to step up the frequency for this high-frequency lighting system. This is the first fluorescent lighting installation in which 60-cycle current has been converted to higher frequencies (360 cycles) without rotating equipment.

One new item is a novel fluorescent "sign" lamp consisting of a clear T-12 tube with the physical and electrical characteristics of a 24-inch 20-watt standard fluorescent lamp, but containing a thin plate of glass extending the length of the lamp with a sign message silk-screened on it in several colors of fluorescent phosphors. In operation only the message glows.

Two manufacturers have introduced additional variations of white fluorescent lamps. One, termed "Snowlite," rated at 4000 degrees Kelvin is designed as a compromise between the 3500K and the 4500K lamps. The other, known as "Vis-A-Ray," has a high green component and is aimed at approaching the visibility curve but without sacrificing a great deal in appearance.

Probably one of the most significant developments in fluorescent lighting during the year has been the re-design of sequence-series type instant-start ballasts, based on the desirable electrical characteristics specified by the lamp manufacturers. The new ballasts operate without sacrificing lamp life, but retain the advantages of smaller size, lighter weight, lower cost and less watts loss compared to the multiple operation ballasts. They make it possible to conserve a considerable amount of material, which is highly important in these times.

Another development that may prove important in conserving materials and improving lighting efficiencies is a new system for high-frequency operation of fluorescent lamps.[3] The system employs a new type of frequency converter with no moving parts which changes 60-cycle current to 360 cycles. At this frequency, large fluorescent lamps require only small condensers as ballasts. The first installation employing this new operating method was installed during the year in one of the test rooms at the Plant Industry Station of the United States Department of Agriculture in Beltsville, Maryland. This installation, shown in Figure 3, is being watched with great interest by lighting engineers since it may pave the way toward further commercial developments.

Agricultural

The new agricultural test room at Beltsville is an underground laboratory in which is provided nearly 3000 footcandles of artificial daylight from fluorescent and incandescent filament lamps. Here experiments in plant growth can be conducted under completely controlled conditions. Some of the interesting results of the tests made in these laboratories were outlined in a paper "Light and Agriculture" last year.[4] Among other important aspects, this work is resulting in an increased knowledge of the effects of photoperiodism (relative periods of light and dark during the day) on the growth and blooming of plants. This new knowledge has been put to practical use in Hawaii where periodic applications of light, during the night, on fields of sugar cane have succeeded in retarding the time of blooming of the plants, with resultant increase in growth and sugar content.

On the farm, fluorescent sunlamps are being used increasingly to protect health and speed development of animals and poultry. Perhaps the big news of the year in this field is the tremendous increase in the use of infrared lamps for brooding of fowl, pigs and livestock in the farm factories that produce our food. New infrared brooder units, some with built-in thermostat control, have greatly spurred this development. (See Figure 2.)

Industrial

One of the great new lighting trends begun during the year is that of providing more comfortable lighting and seeing environments in our places of work. It seems to have suddenly dawned upon the lighting profession that there is no reason why lighting in industry should not be just as comfortable as lighting in the office or school. In fact there are many reasons why better quality lighting should be most

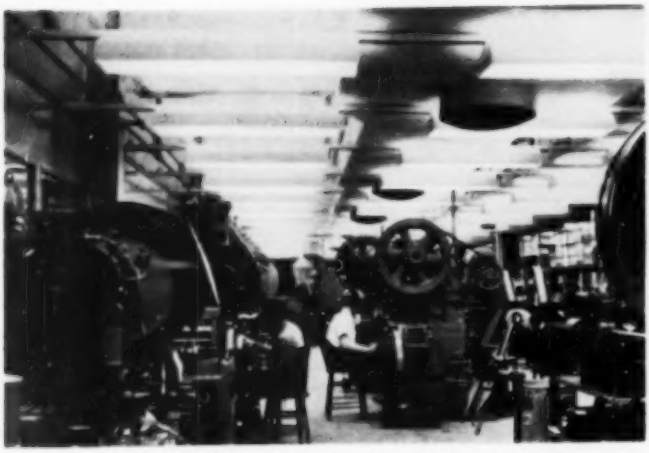


Figure 4. More comfortable lighting and seeing conditions for industry is the keynote of industrial lighting trends today. In this manufacturing plant, light-finished, well-shielded fluorescent luminaires with a component of upward light, keep brightness contrasts low and provide 80 footcandles (initial) of relatively shadow free illumination. A white ceiling, light-colored floor and lighter finishes on walls and machinery help create a good seeing environment.

Figure 5 (above). An "integrated" ceiling system using structural "troffer" beams permits increased flexibility in the arrangement of built-in fluorescent lighting.

worthwhile in industry. Perhaps the trend was started by industry itself. There are several recent outstanding instances where factories have installed commercial type fluorescent fixtures to improve seeing conditions. One example is shown in Figure 4.

Keynotes of this trend are fluorescent luminaires providing better shielding and more upward light with light finishes on the sides and upper portions of the units. Industrial fixtures embodying these principles are just beginning to appear on the market and many others undoubtedly will follow. Hand in hand with the improved lighting goes the necessity for white ceilings, lighter finishes on walls and machinery and lighter floor surfaces for improved eye comfort.

One large engineering and construction company has developed a unique new system of the structural troffer beams shown in Figure 5.[5] These not only serve as wiring ducts, supporting the overhead pipes, air conditioning ducts and ceiling structure, but provide a flexible means of installing recessed fluorescent lighting equipment wherever required by the plant layout.

The difficult problem of lighting instrument panels in industrial control rooms has received a good deal of attention by the Society and excellent solutions have been worked out by the Committee on Control Room Lighting.[6] Experiments with the use of color for identifying groups of instruments and controls have been conducted by a group in the Pennsylvania area and the results appear most promising.

Application of high-intensity mercury lamps for high-bay lighting seems to be expanding rapidly. The fluorescent-mercury lamp announced last year has now been applied in many installations and its use is increasing for medium and high bay lighting.

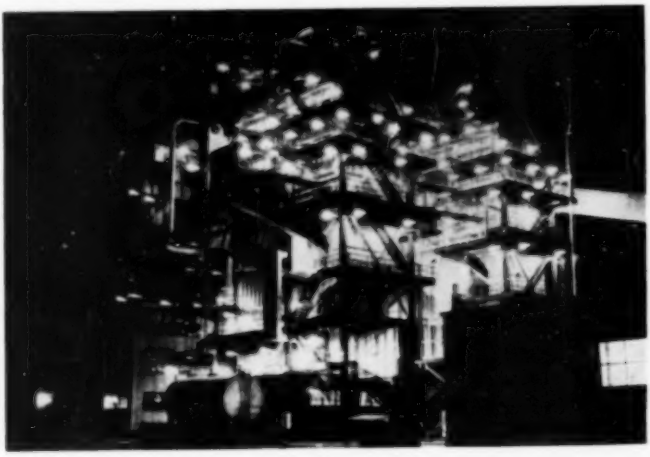


Figure 6 (right). An electric power plant. Some electric utility companies are building steam electric stations outdoors as a means toward more economical generation of electricity. Increasing numbers of outdoor plants, in many industries, pose new problems for the lighting engineer.

The use of black light for industrial inspection of metal parts has developed to the point where large-scale applications of the process are in wide use. It is now employed to inspect for flaws in all manner of fabricated parts ranging from small tungsten rods for radio tubes up to gigantic oil tanks. Some of the larger and more impressive installations are those for inspection of railroad axles, where fluorescent magnetic particle inspection has become standard and is now required by the Association of American Railroads.

Application of germicidal lamps for product protection and processing has become a standard practice in the pharmaceutical industry. A new germicidal device[7] has been developed for irradiation of blood plasma, toxoids, anti-toxins and vaccines. Such processing is now required for all blood plasma used by the Armed Forces.

In this period of industrial mobilization, the ability to carry on work outdoors at night is becoming increasingly important. In several instances, outdoor work areas are being lighted to illumination levels of 50 foot-candles or more. Some industries are moving all or part of their operations outdoors. Oil refineries and chemical plants are good examples of this trend and excellent outdoor lighting installations have been applied in these fields. See Figure 6.

Among the new items of industrial lighting equipment should be noted:

A new all purpose vapor-tight and dust-tight prismatic glass incandescent filament unit for indoor and outdoor use, accommodating 200- or 300-watt lamps. (See Figure 3.)

A new adjustable heavy-duty machine lamp, employing a 75-watt R-30 reflector lamp, for supplementary lighting at heavy production machines. A handy feature of this unit is the provision for locking all adjustments with an Allen wrench where permanent positioning is desired.

An extension cord, trouble light guard and lampholder with a powerful permanent magnet in the base for convenient attachment to machines or any iron structure.

Small, local lighting units consisting of two 4-watt fluorescent lamps mounted in a compact reflector containing the small ballast and equipped with a standard screw base for use in any light socket.

Figure 7a. Fast planes of the U. S. Air Force can be refueled at high speeds and high altitudes by tanker planes equipped with a "Flying Boom" for transferring the fuel. Small fins on this telescoping tube are controlled by the operator, in the tail of the tanker, to "fly" the boom into contact with the receiver airplane.

Figure 7b. This important in-flight refueling operation now can be accomplished at night, as well as in the daytime, as a result of the development of a system of signal lights and floodlights carried on the underside of the tanker plane.

Aviation

A few years ago one of the principal aviation problems involved the traffic control in the air necessary to get planes in and out of airports under low visibility conditions. Radio, radar, and approach and runway lighting have afforded some solution to the problem. Today one of the remaining problems is that of ground traffic control to get incoming planes quickly onto the correct taxiway, clearing the runway for other flights. Experiments are being made with lighted taxiway traffic signs, controlled from the tower, in an attempt to find a solution to this problem.[8]

A brand new idea, developed in conjunction with the so-called "Flying Boom" method of in-flight refueling, makes it possible for a tanker plane to refuel fast bombers at night.[9] A special PAR-36, 50-watt 28-volt lamp was designed for use with this new device. Three of these lamps floodlight the underside of the wings and the fuselage of the tanker plane while ten others transilluminate direction signals, operated automatically by microswitches attached to the boom, to instruct the receiving pilot in maintaining his position while refueling. (Figure 7.)

Armed Forces

The Navy reports some interesting experiments under way, among which might be noted:

Tests with xenon lamps in long range, portable signaling lights for daytime use.

Figure 8. Several lines of fluorescent valance lighting equipment similar to this appeared on the market during the year. Designed primarily for residence lighting, these packaged units can be supplied with their own traverse rods for draperies; lamps are correctly placed for most effective lighting distribution; and valance boards are held in the right position for good shielding of the light source.

The use of xenon flashtubes for underwater photography.

Ultraviolet black light radiation employed for night refueling of vessels at sea under blacked-out conditions. Present investigation includes attaching fluorescent cloths to hoses, lines and rigging with ultraviolet spotlights mounted on the mast.

From the Corps of Engineers come the following reports:

The portable field hospital operating light, reported last year, is being used in Korea.

All construction machinery of the Corps of Engineers will have the new lighting system developed by the Society of Automotive Engineers. These new work lights consist of a PAR 46 sealed lighting unit in a rugged protective housing with a novel shock absorbing mount. The system is considered a major advance in lighting for construction purposes and may be adopted for commercial use.

At Eglin Field, Florida, "artificial desert sunlight" is being used for testing military material such as raincoats, tents, paint, machinery and people, for ability to withstand severe desert conditions. The installation consists of 144 RS sunlamps mounted at the ceiling on one foot centers. The total energy is fairly close to the characteristics of noonday sunlight but the ultraviolet is more powerful than that found in the tropics. It is reported that a person can be sunburned in this room in one minute.

Government

Visitors to the Library of Congress will observe that new measures have been taken to preserve the original manuscripts of the Declaration of Independence and the Constitution on view there.[10] The documents have been sealed in specially-constructed glass cases containing an inert gas. Special radiation filters and a new lighting system are provided to minimize possible deterioration due to light. The new measures were undertaken after careful research and applied lighting engineering by the U. S. Bureau of Standards.

Results of new studies by the Public Building Service and the U. S. Public Health Service, entitled "The Influence of Lighting, Eyesight and Environment upon Work Production," have been published recently.[11] These studies, conducted in the Bureau of the Census of the Department of Commerce, involved card-punching operations. One of the conclusions drawn is that work of this character requires no less than 50 footcandles of illumination.

The lighting and the interior finishes in the huge new General Accounting Office Building in Washington, D. C. are a fine tribute to the work of the General Services Administration in providing improved seeing conditions in our public buildings.[12] Their engineers not only designed the luminous-indirect, plastic fluorescent lighting fixtures and planned the installation, but they also worked out pleasant new color schemes which will be used for all Government buildings.

Color

The new Government Standard Color Schemes embody the principles of good illuminating engineering; several different choices are provided for various types of interiors so that some variety of well-planned interior treatments are available for government offices.

The general use of a wider variety of interesting color treatments for interiors has become evident. This has been made possible by developments, on the part of the paint manufacturers, to make a wide range of colors easily available.

Where the number of wall colors formerly offered by a single paint manufacturer would number ten to fifteen, now the available colors may number in the hundreds. This has been accomplished by various means. One manufacturer offers concentrated color in tubes which can be added to white paint to achieve numerous combinations, tints and shades. Some mix the color desired by the customer at a so-called "color bar." Others use a system of intermixes of a small number of base colors. With this system, as many as 200 different color gradations are available from one manufacturer's line of approximately 15 base colors.

It is also interesting to note that the lighting engineer's demand that light reflection values for each color be noted on the label is bearing fruit. A few manufacturers are adopting this practice.

The use of brilliantly colored daylight fluorescent materials in commercial products has grown by leaps and bounds during the past year. Today, all sorts of commercial articles from hats to shoe laces are manufactured in these brightest of all materials. A new development in this line is that of daylight fluorescent gravure inks. We may soon see magazine advertisements in these glowing colors.

One nationally known magazine has sponsored a plan for correlating colors in interior decoration, furnishings,

appliances and other merchandise used in the home. It is sponsoring a carefully selected group of colors, which may be changed somewhat from year to year, and suggesting that decorators, designers and manufacturers employ these standardized hues for better color harmony. Several manufacturers of residence lighting equipment have already cooperated with this program in the finishes and decorations of their products.

Residence

One of the first residence lighting fixtures to tie in with the new scheme of standard colors is a new "Laundrylite" using two 33-inch 25-watt fluorescent lamps. Luminous plastic sides in this unit provide upward light and give it a most attractive appearance. Simplicity of installation should make this fixture popular for work areas in the home.

The appearance on the market of packaged valance lighting equipment (see Figure 8) is one of the important developments of the year in residence lighting. Last year the first of these lines of units was announced. This year there are at least six manufacturers supplying such equipment.

As ceiling heights in new homes have become lower and lower, the glass ceiling fixtures for them seem to have become flatter and flatter to the point where the lamps were squeezed so close to the glass that unpleasant bright spots were very evident. Some of the fixtures became so flat that the lamps were visible over the top of the glass panel. We note evidences of improvements in engineering and design of some of the newer ceiling fixtures this year. In some of the new designs the glassware has been turned up around the edges concealing the lamps and allowing them to be moved further from the glass without adding depth to the fixture.

A new semi-indirect adaptor-type center-ceiling fixture has been placed on the market. This consists of a shallow glass pan, available with several types of decoration, above which are mounted two lamp sockets in a horizontal position; a screw base adaptor permits installation in any single ceiling socket. A pull-chain switch is so mounted that the ball chain drops through the hollow stem in the center of the glass panel. The chain may be removed if the outlet is switch-controlled. It is understood that larger three-lamp adaptor fixtures may be available in the near future.

Among the new arrivals on the homelighting scene are ceiling mounted luminaires which may be raised to the ceiling for general illumination or pulled down for local lighting over a table or desk. This is accomplished by suspending the unit from a flexible cord attached to a spring-loaded reel. One such unit is illustrated in Figure 9a.

Last year the Progress Report noted some interesting designs in table and floor lamps consisting of a pottery urn concealing the lamp bulb, with a large adjustable shallow dish reflector above to diffuse and direct the light. Similar units for wall mounting are now available, one of which is shown in Figure 9b. Such portable lamps seem well suited to rooms decorated and furnished in the contemporary manner.

Certified Lamp Manufacturers have added to their lines a large new table lamp designed for the 100-200-300-watt three-lite lamp. A new form of glass diffusing bowl has been made available for use in the larger CLM portables. This is made in one piece, including the flared crown at the top of the bowl which had been formed of a separate metal spinning in previous models.

A new novelty is a tiny keyhole light which can be fastened above the keyhole on outside doors; it consists of a neat metal housing containing a penlight battery and lens-end flashlight lamp.

An I.E.S. contribution which should prove of material value to residence lighting equipment designers and lighting specialists was the publication of a report entitled "The Functional Visual Activities in the Home and the Location and Extent of the Associated Areas to Be Illuminated"[13] These studies furnish fundamental data for determining basic dimensions, shielding angles, lighting distribution and placement of lighting equipment.

Another definite contribution to better residence lighting is the new I.E.S. publication "Contemporary Lighting in Modern and Traditional Interiors." This booklet should benefit those wishing to design lighting that goes beyond the simple necessity of providing light where it is needed. The development of a system of Home Light Conditioning Recipes was a major event of the year. Perhaps for the first time, these recipes translate illuminating engineering into terms which can be understood and used by the average householder. With the aid of a tape measure and the recipe book, anyone can check the suitability of his present lighting and determine what to do to improve it. Electric

Figure 9a. This plastic and metal unit for the home can be raised to the ceiling or pulled down lower when desired. A take-up reel in the canopy (with an action like the spring-roller on a window shade) does the trick.

Figure 9b. Several unusual designs in portable lamps for the modern interior have made their appearance. This wall model has a colorful ceramic lamp housing with an adjustable reflector of fiber glass above.

utility companies and others have sponsored the showing of Light Conditioned demonstration homes to show what can be accomplished in the average residence with readily available lighting equipment, through the use of these recipes. The first of these homes was demonstrated in September 1950. In September 1951 more than 250 such Light Conditioned homes were on exhibit.

Street

Within the past few years there has been a great deal of activity and public interest in the improvement of street lighting, to the extent that entire communities have laid plans for American Standard Practice illumination of all their streets. A few have already completed such overall lighting improvements. Inquiries by the I.E.S. Committee on Street and Highway Lighting have revealed some interesting facts on this point:

The current I.E.S. standard practice for street lighting was made an American Standard in 1947, at which time the street lighting in no community conformed to the recommended minimum values throughout. In 1948 one community, Homestead, Pennsylvania, is reported to have lighted every street and alley to this standard. Perhaps the first sizeable community to attain this goal is Cleveland Heights, Ohio, which this year finished a three-year street lighting improvement program involving some 4,000 units lighting all of its 122 miles of streets.[14] Neighboring communities expect to accomplish the same objectives shortly. In the Cleveland area, more than 550 miles of street lighting have been brought up to current American Standards.

Chicago has installed 450 miles of street lighting equaling or exceeding the Standard Practice and expects to add 300 miles more in the next two or three years.

Atlanta, Georgia will probably be the first large city to meet these standards. In that city all principal traffic arteries have been so lighted and the remainder of the program is scheduled to be finished in 1952.[15]

The first fluorescent street lighting to meet the American Standard Practice was installed in Detroit, Michigan during the year. This half-mile stretch of fluorescent lighting is being studied with interest by lighting engineers all over the country.[16]

The application of high-intensity mercury lamps for street and highway lighting shows spectacular growth. It is estimated that there are approximately 2,500 miles of mercury-lighted streets in this country today.

Principally in the Chicago area, the use of mercury street lighting units for floodlighting the fronts of commercial buildings seems to be attaining considerable popularity.[17] In that area more than 2,000 mercury street lighting units have been installed for this application in the past two years.

In St. Paul, Minnesota a new type of incandescent filament street lighting unit designed to be mounted on the face of buildings has been used to light a main downtown business street, eliminating heavy street lighting standards and suspension units.[18] These new luminaires employ the 20-inch diameter convex lens shown in Figure 2. The original 22 block installation consists of 222 units mounted 26 feet above the pavements. More luminaires have been ordered for extension of the lighting system.

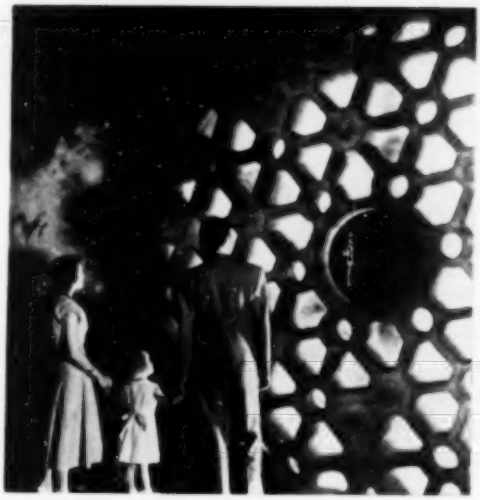


Figure 10. At the new showplace of the glass industry, The Glass Center, Corning, N. Y., may be seen the "largest piece of glass in the world"—the first casting for the 200-inch Palomar telescope mirror—transilluminated in glowing amber light. Exhibits of the latest developments in lighting glassware and historical displays of the use of glass in lighting units are of particular interest to the illuminating engineer.

Commercial

Installations of a new prismatic-glass surface-mounted fluorescent ceiling fixture present the appearance of a built-in lighting job because the luminaires have a depth of only 4½ inches and the glass panels curve upward at the sides to meet the ceiling. The lens-plates produce excellent brightness control both crosswise and lengthwise while providing a desirable downward distribution of light.

A new type of light-controlling lens-plate has been designed for use with 150-watt filament lamps to illuminate vertical surfaces from a ceiling-mounted fixture. One unique feature of these square plates is that they are curved or bent to the correct angle for lighting a wall surface from above.

Further development in lightweight water-white glass lens panels, announced last year, has resulted in the production of thin, curved lens panels four feet long for application in fluorescent fixtures or built-in lighting. These long, clear glass plates are formed by "sagging" the panels into the desired contour.

A new look is becoming evident in continuous row fluorescent lighting installations through the application of long diffusing plastic panels formed by extrusion or molding. These long rigid panels can be butted end-to-end

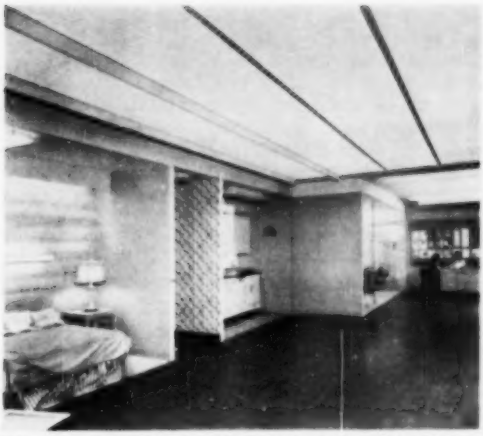


Figure 11. "Packaged" systems of luminous ceiling fluorescent lighting are featured in this recently remodeled area of the Chicago Lighting Institute. Up-to-the-minute demonstrations of residential, commercial and industrial lighting also have been added.

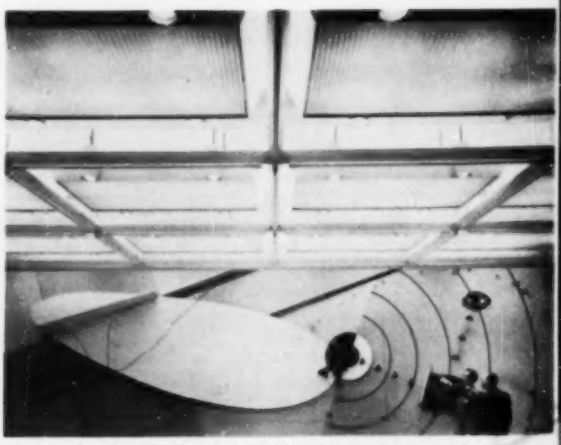


Figure 12. The Lighting for Mobilization Center, opened during the year in the Lighting Institute at Nela Park, Cleveland, Ohio, affords facilities for demonstrating the principles of better lighting and the results achieved by improved seeing environments.

in a continuous fixture to give a perfectly smooth line of light. One type of luminaire of simple and neat appearance employs a large diffusing cover of molded plastic in one piece 15 inches wide by 4 feet long.

Another manufacturer has produced a louvered fluorescent fixture in which the cross louvers may be removed individually for easy cleaning. These louvered sections are formed of short strips of tempered-metal Venetian blind slatting and are easily snapped into place by means of a spring clip attached to them.

Installations have been reported in which fluorescent sunlamps have been added to general lighting in windowless offices. In one such installation, a total of 220 of the 40-watt sunlamps are mounted on the ceiling in individual reflector units over an area of 46,000 square feet. It is said that they provide the equivalent of summer sun during an eight-hour day.

A new idea in office lighting is the combination of louvered fluorescent troffers and luminous ceiling elements. In most troffer lighting installations, the ceiling areas between units appear relatively dark. In one experimental installation, thin corrugated plastic sheets were used to produce luminous ceiling panels between the troffers.[19] The resultant reduction in brightness contrasts renders the lighting pleasant and comfortable to the eye.

Luminous ceiling lighting systems have not been confined to the use of plastic panels entirely. Several office lighting installations have been made using a full ceiling area formed of glass lens plates to control brightnesses in the field of view while giving a general luminous impression overhead. Complete luminous ceilings of "Photalite" louvered glass have been installed. As reported previously, these plates of photosensitive glass have tiny louvers "photographed" completely through the thickness of the plate. Incidentally, a new development in photosensitive glass has resulted in large glass sheets having the appearance of natural marble. This has been done by "photographing" a picture of an actual piece of marble through the thickness of the glass. This innovation may be of some interest to those designing built-in lighting in monumental marble buildings.

One of the significant developments of the year has been the marketing of complete "packaged" corrugated plastic luminous ceiling installations by several manufacturers. (See Figure 11.) Some of these not only provide a complete lighting package but also supply acoustical treatment[20] and means for integrating the air conditioning system with the lighting. There have been a number of such installations in which the area above the luminous ceiling is used to provide a plenum chamber for the air conditioning.

One ingenious design for schoolroom lighting has been noted in which both natural daylight and artificial illumination are controlled automatically.[21] The room has a luminous ceiling of glass-fiber-reinforced corrugated plastic, with a large skylight of the same material some distance above it. Just below the skylight are a series of opaque fins or louvers which are closed or opened electrically. These louvers are controlled by a photocell in the room, set to limit the brightness of the luminous ceiling to produce a maximum of 150 footcandles on the desks. If the natural lighting falls below 35 footcandles, another photocell turns on artificial lighting above the luminous ceiling to provide an additional 35 footcandles. Thus, the illumination in this classroom can never fall below the I.E.S. minimum standard of 30 footcandles.

A new fluorescent fixture has been announced for chalkboard lighting. Designed for 96-inch T-12 fluorescent lamps, or shorter units where necessary, this specular metal trough reflector unit, when added to good general classroom lighting, will build up the illumination on the board to 100 footcandles.

A new and simple device for show

window and display lighting consists of a metal sphere with a circular opening just large enough to accommodate a PAR-38 spotlight or floodlight lamp. A simple triangular stand, placed on the show window floor, shelf, or case top holds the sphere and allows it to be set in any position.

During the year the world's largest bus terminal was built in New York City. All three concourses in this terminal are well-illuminated by built-in fluorescent lighting. The 31 escalators serving the concourses have green fluorescent lamps mounted at top and bottom behind the moving treads. Intense green light filtering through openings in the treads furnishes a clearly evident warning signal at the ends of the escalator.[22]

Another new addition to the skyline of New York City is the United Nations Office Building, forty stories high and with fluorescent lighting throughout. The huge glass windows, covering most of the exterior are of infrared-absorbing glass to filter out some of the radiant heat energy from the sunlight. A total of five acres of this glass is used in the building. Visitors will note an ingenious new device in the elevator signals throughout the building. Instead of the usual push buttons for signaling the elevator operator, an electronic device is employed so that it is necessary to merely touch the "up" or "down" indication on the elevator call plate and the signal operates immediately.

It is reported that one church on Fifth Avenue, while redecorating and relighting the interior, also added built-in facilities for brilliant illumination of pulpit and choir to permit future televising of the services.

A new control system for color lighting in theatrical and display work has been installed in several show windows in New York City and has been used in a number of theatrical productions. Any desired color can be obtained by the operation of a single dial on the control panel, or the unit can be operated automatically to produce a pre-set arrangement of color changes.

Luminous Advertising

A spectacular lighting scheme, employing the color control system mentioned above, has been installed over the entrance to a large office building in New York. The design consists of metal honeycomb louver sections shown in Figure 14, which rise from the ceiling of the elevator lobby to a height of 40 feet on the building front. Behind these cells are massed a total of 1,932 150-watt PAR-38 floods with color roundels, representing a total connected load of 280 kilowatts. Since these lamps are above a floor area 43 feet wide by 20 feet deep, it may be said that there is a connected load of 343 watts per square foot. Large quantities of air, forced past the lamps, extract a good deal of the heat. Electrically, this huge luminous area is divided into 48 sections in each of which can be created a full range of color combinations. Myriads of patterns and colors can be set manually or changed by an automatic programming control. During the daytime, photocells on the face of the building are arranged to compensate for daylight by decreasing or eliminating the proportions of white light in the color combinations.

An innovation in large spectacular signs is the use of repeating flashtubes to simulate the bursting of fireworks. Several such signs are in use, operated by standard sign flasher mechanisms, simulating the ascent, flash and color bursts of sky rockets.

There have been several new developments in the use of natural color photographic transparencies for advertising purposes:

One concern has succeeded in making excellent reproductions of color photographs, in large quantities, on sizeable sheets of thin white plastic. The picture is reproduced not only on the front of the plastic sheet, but also in reverse on the back in perfect register. This results in clearer, more colorful pictures when transilluminated and good appearance when seen unlighted.

Three-dimensional color photographic transparencies now are commercially available. In some of these transilluminated advertisements a second three-dimensional picture appears and disappears as the observer moves past. This ingenious device makes use of a thin sheet of clear plastic with tiny vertical cylindrical lenses molded into the surface. Since there are about 64 lenses per inch, they are practically invisible. At the back of each lens are four tiny strips of color, each representing a portion of a color photograph. When viewed with one eye, each lens expands one color strip to the width of the lens and a complete picture appears across the surface. Viewed with the other eye, a second set of color strips is seen. Thus, with both eyes a complete 3-dimensional color photograph is viewed. When the observer moves his head half the distance between the eyes, two more pictures appear and a different 3-dimensional photograph comes into view.

A relatively new process of color photography makes use of a color negative from which color enlargements may be "blown up" to any desired size. These

Figure 13. In this San Francisco store, an unusual luminous ceiling is formed of shallow plastic domes, the larger ones six feet eight inches in diameter and the smaller twenty-two inches. Fluorescent lamps and skylights above furnish soft illumination by day or night.

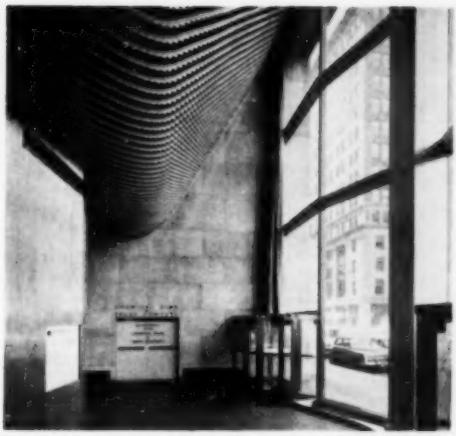


Figure 14. View of office building lobby showing hexagonal louvers back of which are installed almost two thousand colored floodlights operated by the new color control system. Myriads of patterns and colors can be set manually or changed by an automatic programming control.

Figure 15. This huge color transparency attracts much attention in Grand Central Station, New York, N. Y. The lighted picture area is about 60 feet long by 20 feet high. Illumination is from fluorescent luminous tubing behind the photographs.

enlargements are made in sections, on wide strips of film, which are then pieced together to form the entire picture. Large transilluminated signs, employing this technique, are appearing in many cities. One is shown in Figure 15.

Motion Picture

The production of a new type of 35 mm color motion picture film is making widespread changes in motion picture studio lighting techniques. The film formerly used for practically all color movies was balanced to daylight color temperatures and the illumination required for basic exposure was in the order of 500-600 footcandles. This meant that incandescent filament lamps used for set lighting had to be equipped with color filters which absorbed about 60 per cent of the available light. The new color film, announced this year, is balanced to the color quality of tungsten filament studio lighting lamps. This means that these lamps can now be used without color filters. In addition, the sensitivity of the new film is so high that only 100-200 footcandles of illumination is required for proper exposure. Now incandescent set lighting can be used to a greater extent than ever before and illumination levels may be reduced greatly.[23]

Another new development is that of a 5-kilowatt fresnel-lens studio lighting unit with remote-control motors for aiming and for focusing from spot to flood. Even with these added features, the new unit weighs less than half as much as earlier equipment.

Measurement and Research

Among the new instruments available for laboratory and illuminating engineering work should be noted:

A new contrast-brightness threshold meter for visibility measurements.[24]

A direct-reading color densitometer for measuring densities in color or black and white either by transmission or reflection.

A new form of brightness meter convenient in size and operation.

A laboratory microphotometer capable of measuring the brightness or reflectance of a "period" in small printed

Figure 16. Lighting of this new department store in Rotterdam, Holland, has a number of interesting features. The louvered units can be set anywhere in the gridwork, suspended about 30 inches below a midnight-blue ceiling. Each unit, 4 feet long by 2 feet wide, contains two 4-foot fluorescent lamps and two silvered-bowl lamps in aluminized reflectors. The incandescent filament lamps serve as ballasts for the fluorescent tubes, operated on a 250-volt circuit.

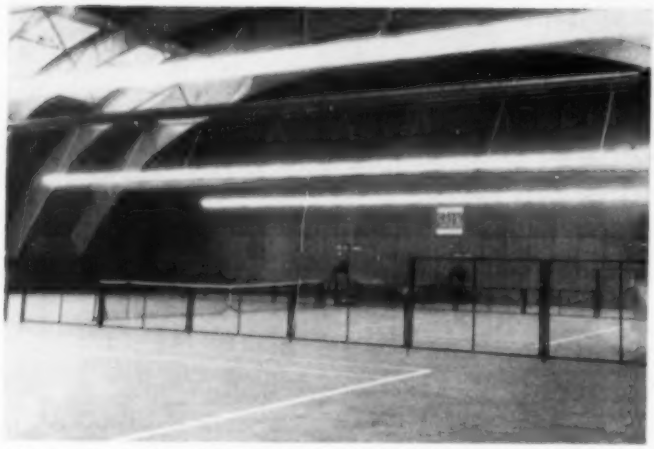


Figure 17. In Sweden, these tennis courts are lighted by continuous fluorescent reflectors running down both sides of each court. The luminaires are cross-louvered and contain two rows of fluorescent lamps.

copy and accurately determining its contrast with the background.

One lamp manufacturer has constructed a new Lighting Facilities Laboratory to obtain new, accurate data for illumination design with today's variety of light sources and lighting systems. The test room is extremely flexible in construction. The floor area can be changed from 12 feet square to 30 feet square or any proportions in between. The ceiling can be adjusted to any height up to 16 feet. The reflectances of all surfaces can be changed by means of removable color panels and any type of lighting system may be installed. To speed the tedious work of lighting measurement, a photocell is arranged to run back and forth on a track which moves down the length of the room, automatically scanning the entire working plane. Recording instruments chart the lighting distribution and total the measurements.[25]

The work undertaken by the I.E.S. Research Fund is beginning to bear fruit. Its accomplishments so far have been well worthwhile and continued achievements are certain to further the progress of illuminating engineering.[26]

Figure 18. The auditorium of the Lighting Service Bureau in London, England, has been remodeled this year to present the latest conceptions in design and illumination techniques.

Lighting Abroad

The foreign correspondents of the Committee on Progress report a number of interesting lighting applications, a few of which are illustrated in this report. Among those not shown, the following may be of interest:

In a Paris theatre, a trelliswork in front of the main curtain is covered with floral designs painted in fluorescent colors and lighted by black light. The trellis is made in two halves which move to the sides, at the start of the show, forming a colorful fluorescent prescenium arch.

A ski jump in the French Pyrenees has been equipped with well-designed floodlighting for use at night. The projectors are so located that they do not appear glaring to either skiers or spectators. It is reported by the skiing enthusiasts that they prefer to use the ski jump at night with the new lighting rather than in the daytime because they are bothered by the brilliant reflection of the snow in bright sunlight.

In the Scandinavian countries a great deal of ingenuity is evident in the design of decorative and practical lighting fixtures. Some of the artfully designed indirect fixtures have glass plastic or metal decorations suspended above to add motion and sparkle.

In London new lighting has been installed in the House of Commons where translucent panels, illuminated by luminous tubing, are set in squares between the wooden beams of the high ceiling.

Prominent features at the Festival of Britain were the many novel and spectacular lighting schemes which made the grounds and exhibits a pleasing spectacle at night.

This year, 18 delegates from the United States, all of them well-known and active I.E.S. members, attended the sessions of the International Commission on Illumination in Stockholm, Sweden. Their reports and observations on lighting abroad added something of an international flavor to the I.E.S. National Technical Conference in Washington.

References

1. Slauer, R. G.: "Recent Developments in High Wattage Tungsten Lamps," (abstract), ILLUMINATING ENGINEERING, Vol. XLV, No. 9, p. 544 (September 1950).
2. Payne, Elmer C., Mager, Eric L., Jerome, Charles W.: "Electroluminescence — A New Method of Producing Light," ILLUMINATING ENGINEERING, Vol. XLV, No. 10, p. 688 (November 1950).
3. "2,000 Ft-c with Slimlines in High Frequency System for Underground Greenhouse," *Magazine of Light*, p. 3 (September 1951).

4. Ditchman, J. P.: "Light and Agriculture," ILLUMINATING ENGINEERING, Vol. XLVI, No. 6, p. 276 (June 1951).
5. "Flexible Factory," *Architectural Forum*, p. 146 (April 1951).
"Troffer Beam System," *Magazine of Light*, p. 18 (September 1951).
6. "Lighting of Control Rooms," ILLUMINATING ENGINEERING, Vol. XLVI, No. 6, p. 319 (June 1951).
7. "Germicidal Lamps at Work in the Medical and Biological Fields," *Magazine of Light*, p. 5 (September 1951).
8. Warnkow, Martin A.: "Visual Aids for Airport Ground Traffic Control," (abstract), ILLUMINATING ENGINEERING, Vol. XLVI, No. 9, p. 477 (September 1951).
9. "Aerial 'Traffic Lights' Aid Refueling of U. S. Airforce Bombers," *Magazine of Light*, p. 22 (September 1951).
10. "Preservation of the Declaration of Independence and the Constitution of the United States," National Bureau of Standards Circular 505.
11. Endres, L. M.: "Light, Color and Environment in Government Offices," ILLUMINATING ENGINEERING, Vol. XLVI, No. 10, p. 577 (November 1951).
12. Coghlan, Thomas F.: "Public Buildings Service in the Lighting Field," ILLUMINATING ENGINEERING, Vol. XLVI, No. 10, p. 549 (November 1951).
13. "The Functional Visual Activities in the Home," ILLUMINATING ENGINEERING, Vol. XLVI, No. 7, p. 375 (July 1951).
14. "Cleveland Heights Street Lighting Program," *Street Lighting Magazine*, p. 10 (May-June 1951).
15. "Atlanta's Five-Year Plan of Street Lighting Modernization," *Street Lighting Magazine*, p. 13 (May-June 1951).
16. Schronk, L. J.: "Brightness Patterns on Pavements with Elongated Light Sources," (abstract), ILLUMINATING ENGINEERING, Vol. XLVI, No. 9, p. 483 (September 1951).
17. "Display Lighting a Store Front," ILLUMINATING ENGINEERING, Vol. XLVI, No. 2, p. 103 (February 1951).
18. "St. Pauls' White Way of Flash Building-Front Lights," *The American City* (August 1950).
19. Oetting, R. L.: "Troffers and Luminous Ceilings Go Well Together," ILLUMINATING ENGINEERING, Vol. XLVI, No. 10, p. 543 (November 1951).
20. Wakefield, T. W.: "Light and Sound Absorption," ILLUMINATING ENGINEERING, Vol. XLVI, No. 10, p. 567 (November 1951).
21. "School with Controlled Daylighting," *Architectural Forum*, p. 158 (July 1951).
22. "Lighting the World's Largest Bus Terminal," *Lighting and Lamps*, p. 16 (December 1950).
"New York's Bus Terminal Pioneers New Electrical Ideas," *Electrical World*, p. 113 (March 26, 1951).
23. Blount, Richard: "Lighting Requirements of a New Professional Color Film for Motion Pictures," ILLUMINATING ENGINEERING, Vol. XLVI, No. 8, p. 415 (August 1951).
24. Cottrell, C. L.: "Measurement of Visibility," ILLUMINATING ENGINEERING, Vol. XLVI, No. 2, p. 95 (February 1951).
25. Potter, Wentworth M., and Russell, Anson H.: "A New Laboratory for Lighting Design Data," ILLUMINATING ENGINEERING, Vol. XLVI, No. 9, p. 449 (September 1951).
26. "Research Gives the Answers," ILLUMINATING ENGINEERING, Vol. XLVI, No. 8, p. 383 (August 1951).

An Analysis of Fluorescent Luminaire Brightness

Additional Discussion and Rebuttal on Paper by John J. Neidhart

(Published November ILLUMINATING ENGINEERING, pp. 569-576)

RAY P. TEELE*: The presentation of brightness data as a polar curve has much to recommend it and the use of the left hand side for endwise values with the crosswise values on the right hand side also appeals to me. The entire brightness story is given at once in a very concise way.

The most serious question raised is whether average brightness or maximum brightness is the more representative of visual reaction. The work of Holladay and recent work by Guth indicate that small patches of light brightness contributing but little flux at the eye are just as effective in producing glare or discomfort as are larger areas having lower brightness and producing several times more flux at the eye. The surrounding area has a brightness which influences the glare effect of small areas of high brightness and the presence of adjacent areas of lower brightness definitely influences the sensation of discomfort or glare from these small areas. This is being studied by Guth, by Petherbridge and Hopkinson and their experimental work may resolve the question of the value of average or maximum brightness measurements as a criterion for evaluating luminaires.

It does not seem that it is time to give up maximum brightness and consider only average brightness as Neidhart suggests. The relationship between the brightnesses of small areas of high brightness and bordering areas is not a simple one and possibly we should give both maximum and average values until we have more experimental data to guide us as to which is the better criterion. Possibly the criterion for comfort is a consideration of both values, maybe one of them as a base and their ratio would be sufficient.

*National Bureau of Standards, Washington, D. C.

JOHN J. NEIDHART*: Mr. Teele's remarks are much appreciated, particularly since he is chairman of the Illumination Performance Recommendations Committee. Part of this committee's task is the classification of luminaire brightness characteristics, and I hope that the last sentence of Mr. Teele's discussion is an indication that he believes that this classification should be based upon average brightness with maximum brightness included only in the form of a limiting ratio that should not be exceeded.

The best answers to the questions raised in Mr. Teele's second paragraph are given in the discussion by Messrs. Guth and Meaker published in the November 1951 issue of IE shortly after Mr. Teele's discussion was prepared. The most significant point that should be noted is that these small areas of high brightness are generally troublesome only when one assumes direct fixation on the glare source. Most of the comfort evaluation systems today do *not* assume such fixation.

I agree that it is not time to give up maximum brightness and consider only average brightness. There seems to be no reason, however, for not switching immediately to average brightness as the primary criterion with maximum brightness data toned down to the form of a ratio. Again, it is hoped that the maximum brightness used for this ratio is more precisely specified than at present with perhaps an even smaller aperture than the one square inch being used by *all*.

*Author.

Questions and Answers on light sources

The I.E.S. Committee on Light Sources, under the chairmanship of E. H. Raddin, has prepared this listing of answers to frequently-asked questions. Readers are invited by the Committee to submit similar questions of general interest on light sources, to be considered for publication from time to time. Questions may be sent in care of Society Headquarters.

Can all fluorescent lamps be operated on direct current?

Yes, with proper auxiliary equipment. On direct current, of course, one lamp electrode is always cathode, the other anode. The mercury ions formed in the discharge flow toward the cathode. After a period of a few hours operation in this fashion, all the mercury vapor as well as condensed mercury will be collected at the cathode end of the lamp and the anode end will consequently be dark, since there is no mercury vapor in that area to generate the necessary ultraviolet. In short lamps, such as the 15T8, or 20T12, there is usually enough back diffusion of mercury vapor so that this effect is not noticeable. With longer or thinner lamps, it is necessary to provide a switching arrangement to reverse the lamp connections end to end every few hours in order to operate them satisfactorily on d-c.

What per cent of the light output of high intensity fluorescent mercury lamps is in the red region of the spectrum?

Approximately 10 per cent of lumens are in the red band (600 to 700 millimicrons).

What is the effect of operating an incandescent filament lamp at other than rated voltage?

Over-voltage applied to the lamp will cause short lamp life with a higher light output. Voltage 5 per cent above normal results in 16 per cent more light, 8 per cent more wattage and 40 per cent shorter life. Under-voltage will lengthen lamp life and will result in a lower light output. Voltage 5 per cent below normal results in 16 per cent less light, 8 per cent less wattage and 70 per cent longer life.

How many filaments are there in a 3-lite lamp?

A 3-lite lamp has two filaments. These filaments consume different wattages and operate separately or in combintion to produce three levels of illumination.

What part of the total tungsten metal used in the United States is applied to the manufacture of lamps?

In the lamp business, a little tungsten goes a long way. For example, one pound of tungsten wire drawn to .00185 inch diameter is 8.5 miles long and provides filaments for over twenty-five thousand 60-watt lamps. At present, the lamp industry consumes about two per cent of the tungsten used in the United States.

Why are incandescent filament lamps operated over-voltage for lighting a baseball or football field?

Lighting installations for sports fields are rather high in cost. To limit this cost, the lamps are frequently operated 10 volts or 10 per cent over-voltage so that the lamps will produce about one-third more lipht than their normal rating, and thereby permit the use of less fixtures for a desired amount of light. In this way, installation costs and operating costs are reduced. As the burning hours per year are usually only 200 to 400 hours, the lamps are usually group replaced.

Why are some incandescent filament lamps for street lighting classified by amperes and lumens and others by watts and lumens?

Before there were incandescent filament lamps, street lighting lamps were carbon arc types and most of them operated in series with each other on constant current circuits.

These arc lamps were rated in amperes, and when incandescent filament lamps were developed to replace them, they were rated and operated in the same manner. The earliest incandescent filament street lighting lamps were, therefore, also of the series type. The lamps were rated in candlepower and amperes and later in lumens and amperes.

The series lamps are still the most widely used for street lighting, but in recent years, the trend has been to the use of street lighting lamps operated in parallel (multiple) and such lamps are rated in watts and lumens.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Summary of Action Taken at Council Meeting, New York

An all-day meeting of the I.E.S. Council was held December 13 at the Lexington Hotel, New York City. Summary of actions taken follows.

Present were: S. G. Hibben, President, presiding; Past-Presidents, C. H. Goddard, Walter Sturrock; Vice-Presidents, A. H. Manwaring, E. M. Strong; General Secretary, C. C. Keller; Treasurer, R. F. Hartenstein; Directors, G. W. Beals, R. L. Biesele, Jr., N. D. Macdonald proxy for L. A. Hobbs, D. M. Jones, R. A. Palmer, J. S. Schuchert; Regional Vice-Presidents, P. H. Hildebrand, F. P. Labey, C. N. Laupp, R. G. Slauer, F. C. Winkler; A. D. Hinckley, Executive Secretary; C. L. Crouch, Technical Director and Ruby Redford, Editor, and George W. Clark, G. H. Stickney, A. S. Turner, Jr., A. F. Wakefield, M. N. Waterman.

Membership Elections

Among other recommendations on membership elections, the Board of Examiners recommended to Council the election of A. H. Taylor and L. C. Kent, both long-time members of I.E.S., to the grade of Member Emeritus. Favorable action was taken on this recommendation, and on the election of five Members, 80 Associate Members, and 10 Student Members. The names, by Section and Chapter, of these new members are listed elsewhere in the Telecast Section. Current membership statistics are shown in the following tabulation:

September 30, 1951		December 13, 1951
7166	Total Membership	7196
32	Members Emeritus	33*
42	Fellows	43
1709	Members	1711
5174	Associate Members	5160
209	Student Members	249

*Includes 10 Fellows of the Society.

Committee Appointments

Additional appointments of committee personnel were approved by Council. These appointments, listed below, are not shown in the list of Committee personnel published in the December issue of Illuminating Engineering, but will be added, together with any subsequent appointments when the list is published in a later issue. Appointments at the December Council meeting were:

Papers—G. W. Beals, Roy Dahlin, J. O. Kraehenbuehl, W. P. Lowell, K. M. Reid.

Publications—H. H. Magdsick to replace E. H. Church.

Sub-Committee on Editorial Content—O. P. Cleaver, G. F. Dean, R. W. McKinley, H. M. Sharp, T. H. Shepherd, T. D. Wakefield, C. W. Zersen.

Membership—Section and Chapter Representatives—H. A. Bell, F. E. Blair, A. A. Fox, W. A. Newman.

National Technical Conference—R. M. Zabel.

Public Relations and Information—Section and Chapter Representatives—Gordon Brown, Blair E. Plowman, J. D. Stephen, T. S. Taylor, F. S. Walters.

Sustaining Membership—Section and Chapter Representatives—H. V. Oerting, R. W. Staal.

Aviation Lighting—D. C. Miller, Vice-Chairman Secretary, Harry A. Cramer, Irving Fagin, Kurt Franck, Paul H. Greenlee, J. D. Hall, D. S. Little, N. H. McIntyre, T. H. Projector.

Civil Defense Lighting, Sub-Committee West Coast Lighting Advisors—D. M. Finch, K. E. Hollingsworth, T. H. Shepherd.

Daylighting—Sub-Committee, Standard Test and Report Procedures for Daylight Studies—E. E. Vezey, Chairman, W. E. Folsom, Secretary, W. J. Arner, R. W. McKinley, F. K. Sampson, R. L. Biesele, Jr., ex-officio.

Industrial Lighting—I. P. Crevi to replace J. W. Steiner.

Lighting Study Projects in Industry—Homer Elliott.

Textile Industry—D. Mack Woodside.

Lighting Study Projects in Public Buildings and Private Institutions—H. L. Logan.

Auditoriums and Churches—Berlon C. Cooper, J. T. Dunne, C. T. Masterson.

Hotel Lighting—C. I. Sayles, Chairman.

Lighting Maintenance—A. C. Barr, Vice-Chairman, L. M. Endres.

Office Lighting—Sub-Committee on Direct Glare—R. L. Oetting, Chairman, R. W. McKinley, George Taylor, Roger White, R. L. Zahour.

Sub-Committee on Reflected Glare—G. P. Wakefield, Chairman, A. S. Almryde, L. M. Endres, Charles Macy, J. J. Neidhart.

Testing Procedures—Wallace G. Hill.

Lighting Handbook

E. C. Huerkamp, Chairman of the Publications Committee presented a report on the now completed Handbook project, which indicated that the book has been prepared within the budget established for it, and that copies will be mailed on or about January 1st. The report on the Handbook financial operation was referred to the Finance Committee for study.

Following discussion on disposition of the Handbook Committee personnel, action was taken to retain the Committee intact pending any possible changes in the text, and a possible second printing of the new edition.

Policies and Procedures

Duncan M. Jones, Chairman reported on studies made by the Committee on Policies and Procedures, indicating this Committee had prepared definite recommendations concerning new procedures for the Board of Nominees, Board of Fellows, Medal Award Committee and for technical and non-technical reports. The P. and P. Committee's report was referred to the Committee on Constitution and By-Laws for study and recommendation to the February Council.

Other Committee reports were presented, and accepted by Council, from the Committee on Prerequisites in the Profession, the Membership Committee and the Public Relations Committee.

New Chapter—Oklahoma

A petition for a Charter to form a new Chapter of I.E.S. was presented by R. L. Biesele for a group of members in Tulsa, Okla. He noted that all requirements for an I.E.S. Chapter have been met by this group, including an active program of some 47 meetings. Council took action to approve a Charter for the Oklahoma Chapter, with headquarters in Tulsa.

EASTERN PENNA. SECTION

A Section Charter was approved following petition of the Eastern Pennsylvania Chapter for Section status. The petition, presented by Paul Hildebrand, noted that in three years' operation, this Chapter had grown from 52 to 160 members, and had conducted an especially active program of meetings and group projects.

1954 CONFERENCE CITY

Time and place of the 1954 National Technical Conference was approved by Council, on the recommendation of H. P. Steele, Chairman of the Conference Committee. To tie in with the comprehensive celebrations scheduled for the Centennial of Light in Atlantic City, N. J., the I.E.S. National Technical Conference will be held the week of September 12, 1954 at the Chalfont Haddon Hotel, Atlantic City. Philadelphia Section will be host.

Mr. Steele also reported on the progress of plans for the 1952 Conference, to be held next September 8-13 at the Edgewater Beach Hotel, Chicago, and the 1953 meeting the week of September 14, 1953 at the Commodore Hotel, New York City.

Before adjournment, the next Council meeting was set for February 14, 1952 in New York City.

Arizona Chapter Receives Its Charter

A new I.E.S. Chapter was officially inaugurated during special ceremonies in Phoenix, Arizona. Seven engineering organizations witnessed the presentation of the Charter to the Arizona Chapter of I.E.S., at a meeting held November 23 at the Westward Ho Hotel in Phoenix. The Honorable Howard J. Pyle, Governor of the State of Arizona, made the presentation and congratulated the chapter on its formation and its work with the other engineering societies. J. D. Whitnell, temporary Chairman of the chapter, received the Charter.

The Charter was presented at a joint convention dinner that was held for the annual convention of engineers in the State of Arizona. The following organizations were represented: The National Society of Professional Engineers; The Arizona Society of Engineers; The American Institute of Electrical Engineers; The American Society of Civil Engineers; The American Society of Mechanical Engineers; The Institute of Radio Engineers; and last but not least, The Illuminating Engineering Society.

On the next day at a luncheon meeting held in the Adams Hotel the permanent officers of the Chapter were inaugurated.

ARIZONA Chapter receives its Charter at special meeting in Phoenix, November 23. Gov. H. J. Pyle of Arizona (left) is shown presenting the Charter to J. D. Whitnell, Chairman of the new group.

These were: B. H. Hartley, Falcon Engineering Company, Chairman; J. D. Whitnell, Central Arizona Light and Power Company, Vice-Chairman; S. L. Burnham, General Electric Company, Secretary-Treasurer; Bert Keyfauver, Graybar Corporation, Board of Managers; Herman Bell, Architect, Board of Managers; Dr. D. O. Cage, Optometrist, Board of Managers; and A. W. Smith, Central Arizona Light and Power Company, to serve on the Board of Managers in lieu of a past Chairman.

The Chapter has now completed its organization and is ready to take its place alongside the other fifty-one Chapters of the Illuminating Engineering Society for the furtherance of the science of illumination.

Pittsburgh Section Announces Planned Lighting Award

Rules of a Planned Lighting Control open to all members of the Pittsburgh Section of I.E.S. were announced by the Section's Awards Committee recently. Purpose of the contest is to stimulate an appreciation for planned lighting and to offer local members an opportunity to present their own accomplishments in the lighting field.

Entrants submitting the six best reports may be invited to present them before local or extension meetings of the Section. Two top awards will receive $25.00 each.

Contest rules are available from C. E. Miller, 435 Sixth Ave., Pittsburgh 19, Pennsylvania.

Deadline Set for 1952 Conference Papers

The I.E.S. Papers Committee is planning an outstanding program for the 1952 National Technical Conference, in Chicago. It is realized that there are many excellent papers which could be written for this conference and authors are invited to submit their proposals.

The Papers Committee announces that a deadline date of March 1, 1952 has been established for the receipt from authors of outlines of their proposed papers for the 1952 conference. Triplicate copies of outlines of proposed papers should be mailed by March 1, 1952 to R. M. Zabel, Co-Chairman, Papers Committee, c/o Westinghouse Electric Corporation, Lamp Division, Bloomfield, N. J.

If a prospective author receives tentative approval of the outline of his proposed paper he must mail his manuscript to Mr. Zabel at the above address by May 1, 1952. It is the policy of the Papers Committee that no paper will appear on the program unless the manuscript has received the approval of the Papers Committee.

Co-Chairmen of the 1952 Papers Committee are: L. E. Barbrow, Roy A. Palmer, and R. M. Zabel.

Clinic on Lighting for Industrial Production

Three sessions in a full-day meeting were devoted to a Clinic for Industrial Lighting and Safety, held in Chicago, December 7. Sponsors for the clinic were the Chicago Association of Commerce and Industry, Chicago Section of I.E.S., and the Chicago Lighting Institute. A capacity audience of industrialists from several states attended the clinic. Subjects presented were:

Need for Increased Production and Safety in Industry, E. E. Frederick
Fundamental Factors of Industrial Lighting, Wm. D. Richards
Industrial Light Sources, Carl F. Jensen
Outdoor Lighting of Plant and Yard Areas—For Production and Protection, James Weeks
Lighting Production Areas, James Chambers
Inspection Techniques and Localized Lighting Equipment, R. F. Diefenthaler
Lighting Industrial Office Areas for Efficiency, George Gilleard
Infra Red and Ultra Violet Uses in Industry, Harold Bunte
Industrial Distribution Wiring Systems for Lighting, Frank McShane
Exit and Emergency Lighting, F. J. Prindiville
Color Painting and Coding of Industrial Interiors, Walter Granville
Industrial Lighting Maintenance, C. E. Egeler

Chairmen of the three sessions were August Echel, Midwest Editor of McGraw-Hill Publishing Co., B. J. Martin, publisher of *Electrified Industry*, and C. W. Zerusen, Managing Director of the Chicago Lighting Institute.

U. S. Committee of C.I.E. Re-elects Officers

The United States National Committee of the International Commission on Illumination held its Annual Meeting at the Engineers Club, New York, N. Y. on November 28, 1951. Twenty-four members and guests attended the all-day meeting.

Officers elected for the ensuing year are:

President.....Arthur A. Brainerd
Vice-President.....Willard C. Brown
Secretary.....Louis E. Barbrow
Treasurer.....Theodore D. Wakefield

At this first meeting following the Stockholm Sessions, the Recommendations tentatively adopted in Stockholm were reviewed and exceptions taken where the Recommendations were found to be contrary to accepted U. S. practice. Dr. Ward Harrison, recently elected president of the Commission, showed colored movies and Willard C. Brown, Vice-President of the U. S. National Committee, showed colored slides incident to the Stockholm Sessions.

In preliminary preparation for the next international sessions to be held in

(*Continued on page 9A*)

LIGHTING CALENDAR

Society Events

February 14, 1952—Meeting of I.E.S. National Council, New York, N. Y.

March 13, 1952—Meeting of I.E.S. Council Executive Committee.

March 13-14, 1952—South Pacific Coast Regional Conference, Hotel Sir Francis Drake, San Francisco, Calif.

March 20-21, 1952 — Pacific Northwest Regional Conference, Hotel Victoria, Vancouver, B. C.

March 31, 1952—Meeting of I.E.S. National Council, Edgewater Beach Hotel, Chicago, Ill.

April 6-9, 1952—Southwestern Regional Conference, Hotel Tulsa, Tulsa, Okla.

April 20-22 1952—Southern Regional Conference, Hermitage Hotel, Nashville, Tenn.

April 30 - May 2, 1952—Canadian Regional Conference, Hotel General Brock, Niagara Falls.

May 5-6, 1952—Great Lakes Regional Conference, Statler Hotel, Cleveland, Ohio.

May 8, 1952—Meeting of I.E.S. Council Executive Committee.

May 21-23, 1952—East Central Regional Conference, Webster Hall Hotel, Pittsburgh, Pa.

June 18, 1952—Meeting of I.E.S. Council, New York, N. Y.

June 19-20, 1952 — Northeastern Regional Conference, Hotel Preston, Swampscott, Mass.

July 10, 1952 — Meeting of I.E.S. Council Executive Committee.

September 9-13, 1952 — Illuminating Engineering Society, National Technical Conference, Edgewater Beach Hotel, Chicago, Ill.

Industry Events

January 14-17, 1952 — Plant Maintenance Show, Convention Hall, Philadelphia, Pa.

January 17-24, 1952—National Housewares & Home Appliances Exhibits, Navy Pier, Chicago, Ill.

January 21-23, 1952—National Electric Sign Ass'n, Convention & Exhibit, Hotel Sherman, Chicago, Ill.

January 21-25, 1952—Winter General Meeting, American Institute of Electrical Engineers, Hotel Statler, New York, N. Y.

January 28-30, 1952—The American Society of Heating & Ventilating Engineers, 58th Annual Meeting, St. Louis, Mo.

February 7-8, 1952—Instrument Society of America, New York Section, 1952 Regional Conference on Power Plant Instrumentation, Hotel Statler, New York, N. Y.

February 7-9, 1952 — Inter-Society Color Council's 21st Annual Meeting, Hotel Statler, New York, N. Y.

March 3-6, 1952—Institute of Radio Engineers, Convention, Waldorf-Astoria Hotel & Grand Central Palace, New York City.

March 5-8, 1952 — Essex Electrical League, Seventh Annual Electrical Industrial Exposition, Terrace Ballroom, Newark, N. J.

March 10-13, 1952 — National Electrical Manufacturers Ass'n, Edgewater Beach Hotel, Chicago, Ill.

March 28 - April 6, 1952—Chicago International Trade Fair, Navy Pier, Chicago, Ill.

March 24-26, 1952—American Society Mechanical Engineers, Spring Meeting, Seattle, Wash.

March 26-28, 1952 — American Power Conference, Hotel Sherman, Chicago, Ill.

April 1-3, 1952 — Edison Electric Institute, Sales Conference, Chicago, Ill.

April 1-4, 1952—Greater New York Safety Council, 32nd Annual Safety Convention & Exposition, Hotel Statler, New York City.

April 28 - May 3, 1952 — Chamber of Commerce, Annual Meeting, Washington, D. C.

May 4-8, 1952 — The Electrochemical Society, Inc., National Convention, Benjamin Franklin Hotel, Philadelphia, Pa.

May 5-7, 1952 — Engineering Institute of Canada, 1952 Annual Meeting, Hotel Vancouver, Vancouver, B. C.

May 6-9, 1952 — Fourth International Lighting Exposition & Conference, Cleveland Municipal Auditorium, Cleveland, Ohio.

May 12-13, 1952 — Electrical Contractors Association of Ontario, Annual General Meeting, General Brock Hotel, Niagara Falls, Ont.

June 8-21, 1952—International Organization for Standardization (ISO) General Assembly, Council and a Number of Technical Committees, Columbia University, New York, N. Y.

Week of June 9, 1952—44th Annual Convention, National Association of Electrical Distributors, Atlantic City, N. J.

June 23-27, 1952 — Summer General Meeting, American Institute of Electrical Engineers, Hotel Nicollet, Minneapolis, Minn.

Week of June 23, 1952—American Society for Testing Materials, 50th Anniversary Meeting, Hotels Statler and New Yorker, New York, N. Y.

June 30 - July 2, 1952—Canadian Electrical Association, Annual Convention, Banff Springs Hotel, Banff, Alta.

August 19-22, 1952 — Pacific General Meeting, American Institute of Electrical Engineers, Phoenix, Ariz.

September 8-10, 1952—American Standards Association's Third National Standardization Conference, Museum of Science and Industry, Chicago, Ill.

September 8-11, 1952 — Institute of Traffic Engineers, Annual Meeting, Hotel Sherman, Chicago, Ill.

October 1-3, 1952—Canadian Electrical Manufacturers Association, 9th Annual Meeting, General Brock Hotel, Niagara Falls, Ontario.

October 13-17, 1952—Fall General Meeting, American Institute of Electrical Engineers, New Orleans, La.

October 20-24, 1952—40th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

November 10-13, 1952—National Electrical Manufacturers Association, Haddon Hall Hotel, Atlantic City, N. J.

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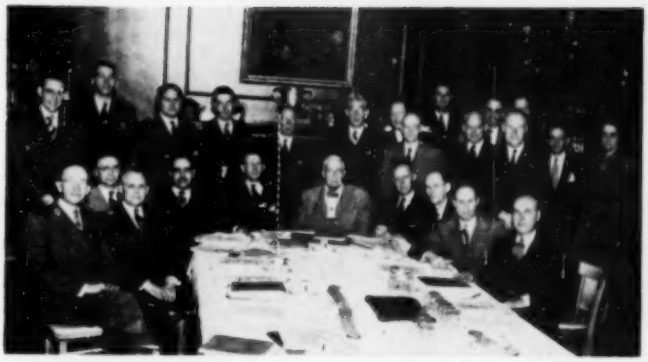

UNITED STATES Committee, C.I.E., annual meeting in New York City on November 28. Those present were left to right first row: Walter Wagner, T. D. Wakefield, Walter Sturrock, L. E. Barbrow, Secretary; Arthur A. Brainerd, President; George H. Stickney, Honorary President; Willard C. Brown, Vice-President; F. C. Breckenridge; Prof. C. D. Fawcett; Ward Harrison, President C.I.E. Second row: C. L. Crouch, Marshall Waterman, F. J. Vorlander, E. H. Salter, W. F. Little, S. G. Hibben, President I.E.S.; Dr. K. S. Gibson, Herbert A. Kliegl, C. A. Atherton, Honorary Secretary C.I.E.; R. J. Whitney, Miss A. E. Wiggins. Top row, right: J. L. Kilpatrick, H. Deming, J. S. Schuchert, H. H. Magdsick.

(Continued from page 7A)

Switzerland in 1955, the scope of the work of the Commission was reviewed in detail, a revised scheme of subdivision of the technical work to be undertaken was developed, and plans were made for carrying on the work of those technical committees the secretariat of which may be assigned to the United States. Although the next Sessions are over three years away, some of the technical committees, and notably the automobile headlighting committee on which Mr. V. J. Roper is principal U. S. Representative, are actively working on problems delegated to them for solution in Stockholm.

Good Housekeeping Emphasized At Industrial Hygiene Congress

During a two-day business Conference of the Industrial Hygiene Foundation at the Mellon Institute, Pittsburgh, Pa., November 14-15, I.E.S. President S. G. Hibben contributed an illustrated survey of the importance of good housekeeping in connection with maintenance of lighting equipment. The connection between general health and hygiene of industrial employees and good lighting was emphasized as a fitting part in any health and welfare program. The influence of dusty working areas, it was noted, is about as important in connection with deleterious effects on work illumination as it might be upon the respiratory functions of the worker. Furthermore, in stressing the importance of periodic and planned cleaning, Mr. Hibben developed an appraisal of related hazards which must be guarded against in the washing of overhead lighting fixtures, together with an explanation of safe and simple methods, leading to the inevitable conclusion that dirt does cause a loss of see ability and extra consumption of lighting power —i.e., that water is cheaper than watts.

An open forum question period at this lighting session developed numerous questions about periodic lamp replacement, over all lamp life, efficiency differences between industrial illuminants and the response of the human eye to various conditions of glare, gloom, color contrasts, flicker and shadows. Obviously, the prevention of dirt was deemed to justify more consideration than it has been given, and this topic brought forth timely discussions of the proper design and placement of lighting equipment with easy maintenance in view, as well as the hygienic planning of air-conditioning systems and dustless work areas to minimize the relatively costly housekeeping of both lighting fixtures and interior painted surfaces.

Included in this hygienic aspect was a discussion of the development of ozone in closed work spaces where short-wave ultraviolet sources are used to purify air and reduce objectionable odors.

Active Interest Shown In Home Lighting

Fifty-four electric utility companies, out of 91 replying to a survey made by the Edison Electric Institute's residential lighting committee, are actively promoting home lighting, with an additional 11 companies planning to begin promotion in this market within the near future.

The 91 companies which supplied data for the survey serve 19,437,620 residential customers, representing about one-half of the industry's total.

Fifty-two utilities stress Certified

(Continued on page 10A)

Be It Resolved

that the officers and Council of the Illuminating Engineering Society record sincere regret at the recent passing of George G. Cousins, Fellow and Member Emeritus, and hereby express their appreciation and gratitude for the notable contribution which he has made to the work of the Society directly and through his intimate connection with the field of illumination during the greater part of his lifetime.

As one of the organizers and first Chairman of the Toronto Chapter, again as Chairman from 1928 to 1930, and as Canadian Regional Vice-President, Mr. Cousins helped to build the solid foundation on which the Society's activities now stand in Canada. Of inestimable value was his work on school lighting with the Ontario Department of Education.

As Treasurer of the Society and through active membership on many Technical and other Committees, George Cousins served the Society as a whole, ably and well. During his terms of office on Council his opinions were highly respected and his sterling character admired.

The fruits of his efforts will long continue to benefit our Society.

"Yes, Hadley, yes! She may be a good teacher, and all that, but think what she'd do to our Harmon technique!

Submitted by Sidney Chilton, member of the Tennessee Valley Chapter, I.E.S., Memphis, Tennessee.

(Continued from page 9A)

Lamps in their home lighting activities. Lecture demonstrations on home lighting are offered to interested groups by 74 utilities, and 65 companies make home lighting calls.

Eighty companies expressed interest in the Planned Home Lighting Program offered by the institute and Better Light Better Sight Bureau. Sixty-one companies requested continued promotion of home lighting in this national program.

Forty of the replying companies cooperate with elementary schools in their service areas in programs designed to teach school children basic facts about light and sight; 45 companies work with junior high schools; and 17 with colleges. Twenty-two companies help to provide training for teachers in this subject.

Naval Research Laboratory Studies Luminous Materials

Experiments with self-luminous and phosphorescent materials, with regard to visibility and lighting characteristics for night time and blackout use, have been made by the Naval Research Laboratory, according to a recent Defense Department technical news letter. Results show that radioactive phosphors are satisfactory for illumination of instrument dials under darkened conditions at ordinary reading distances. Phosphorescent material is useful for large area signs during emergency operations of a few hours' duration, according to their tests.

R. G. & E. Sponsors Advance Lighting Course

The Rochester Gas & Electric Company are currently conducting an Advanced Course in Lighting in six bi-monthly sessions starting January 10. Classes are held in the R. G. & E. auditorium on alternate Thursday afternoons from 2:00 to 4:00 p.m. Each two hour session will be divided equally between lecture and round table discussion.

Textbook for the course is the new 1952 *IES Lighting Handbook*. The registration fee of $7.50 includes the new Handbook and other material supplied. For students already possessing the Handbook, the registration fee is $2.50.

Subjects to be presented at this course include:

January 10—Quantity and Quality Requirements of Lighting—Design Calculations
January 24—Light Sources
February 14—Fixture Design and Characteristics
February 28—Applications: Office and Classroom
March 13—Applications: Store Lighting
March 27—Applications: Factory Lighting, Including Protective.

Back Issues of I.E.S. Transactions Available

A complete file of *I.E.S. Transactions*, dating from January 1922 are available to any worthy institution or individual interested in obtaining them. Anyone desiring these back issues of the *Transactions* may write to: G. F. Prideaux, General Electric Co., Nela Park Engineering Division, Cleveland 12, Ohio.

Chicago Section Papers Committee Scores in IE

An especially effective local Papers Committee functioned last year in the Chicago Section, stimulating papers for possible publication in ILLUMINATING ENGINEERING from Section members. Box score — six papers submitted in 1950, four published, one returned, one pending revisions.

The committee, headed by Eric H. Church as chairman not only stimulated the preparation of papers, but acted as a reviewing board of all material before it was submitted to the Society's edito-

(Continued on page 13A)

CHAIRMEN, past and present of the Montreal Section, I.E.S., gather for Section meeting. L. to r. M. Laflamme; Jos. Thomas; E. Morris, this year's chairman; J. W. Bateman; Duncan Jones; and Arthur Mendel.

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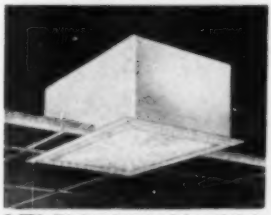
RO 894—Round flush unit is ideal for certain architectural applications. For use where general lighting is required—all glass construction assures economy of operation. For 200 or 300 watt lamp.



R 774—This incandescent unit is particularly desirable for general even spaced lighting. Should be spaced 1½ times the mounting height above the work plane. For 150 watt lamp.

RO 772—These units are designed for use with tile or block ceilings and will exactly replace a single 12" square tile. "T" bar or metal frame construction simplifies installation. For 200 or 300 watt lamp.

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(Continued from page 10A)

rial office. The Committee worked closely with headquarters on the nature of the material to encourage, length of manuscript and final scheduling.

The activity in its first year was considered so worthwhile, that a similar committee has been appointed by the Chicago Section for the 1951-1952 term. This year's Chairman is George Gilleard of Curtis Lighting Inc., who has already held a meeting of the eleven members of the committee, drawing up plans and deciding on specific subjects for next year's submissions.

A project such as this in other Sections and Chapters could result in lively countrywide participation in the Society's publications program, and give good recognition to local members for their outstanding lighting jobs.

CHICAGO Section Papers Committee which met recently to plan subjects of papers from local members, for submitting to IE publications office. Clockwise around table: F. J. Vodica (center), M. W. Ross, J. W. Peterson, G. Gilleard, G. G. Nordeen, G. Marks, M. Feron, W. D. Richards. Also members but not shown are E. H. Church. W. I. Crockett, J. A. Kilp.

4th I.L.E. Exhibit Space Appointed

A complete sell-out of all exhibit space was indicated at the first drawings for exhibit booth locations at the Fourth International Lighting Exposition and Conference. The Exposition which is sponsored by the Industrial and Commercial Lighting Equipment Section of the National Electrical Manufacturers Association will take place May 6th through 9th, 1952, at the Cleveland Auditorium.

According to Mr. S. R. Naysmith, Chairman of the Exposition Operating Committee, 123 exhibit spaces have been sold with only 11 spaces still available at the present time. Mr. Naysmith reports, "Interest in the coming Exposition is greater than I have ever seen it before, and from all indications, it should be the biggest both in number of exhibitors and attendance."

I.E.S. Regional Conferences, 1952

South Pacific Coast	Sir Francis Drake Hotel San Francisco, Calif.	March 13-14
Pacific Northwest	Hotel Victoria Vancouver, B. C.	March 20-21
Southwestern	Hotel Tulsa Tulsa, Okla.	April 6-8
Southern	Hermitage Hotel Nashville, Tenn.	April 20-22
Canadian	General Brock Hotel Niagara Falls, Ont.	April 30 - May 2
Great Lakes	Statler Hotel Cleveland, Ohio	May 5-6
East Central	Webster Hall Hotel Pittsburgh, Pa.	May 21-23
Northeastern	Hotel Preston Swampscott, Mass.	June 19-20

I.E.S. National Technical Conferences 1952, 1953, 1954

September 8-13, 1952 — Edgewater Beach Hotel, Chicago, Ill.
Week of September 14, 1953 — Hotel Commodore, New York, N. Y.
Week of September 12, 1954 — Chalfont-Haddon Hall, Atlantic City, N. J.

British I.E.S. Announces Summer 1952 Meeting

Outlines of papers to be presented before the British I.E.S. annual meeting next summer have been announced. Included in the very comprehensive program is one American speaker—H. L. Logan of Holophane, New York, who will present a paper on "Two Frontiers of Lighting."

The Conference is scheduled for May 20 through 23, 1952 at Easthorne, England. American visitors have received a cordial invitation to attend this conference, which will include some six outstanding speakers on subjects of special interest to illuminating engineers.

Details may be obtained from the Secretary of the Illuminating Engineering Society, Mr. G. F. Cole, whose address is 32 Victoria St., London S.W.1, England.

Third Printing Ordered For Lighting Booklet

"Lighting and the Nation's Welfare," a twenty-four-page booklet prepared as a public service by the National Information Committee on Lighting, Cleveland, Ohio, will go into its third printing, according to Edmond C. Powers, Executive Secretary. The booklet summarizes the vital present-day services of illumination in American industrial production, in public safety, in research and education, and in government.

The wide distribution of the book resulted in numerous inquiries to the Committee for more information on lighting, or for sources of information on specific lighting problems.

Over 35,000 copies have already been distributed; the third printing is for an additional 10,000 copies.

(Telecast continued on page 14A)

New Lighting Handboks Now Being Mailed

At long last, the new 1952 IES Lighting Handbook, over 75 per cent revised, is being mailed. Delayed in publication by the extensive revision found necessary to make this edition truly up-to-date, the Handbook is the product of three years' study by thirty-four technical committees of the Society with total personnel of more than five hundred.

We are sorry it is late; we regret any inconvenience caused by the tardy arrival of this book. But we think that when you receive your copy of this 900-page lighting reference book, you will appreciate the extra time taken to make this Second Edition the comprehensive, authoritative volume that it is.

Heat Treatment "Cure" May Modify Plastic Properties

Heat treatment of plastics to give them desired properties, using methods similar to those now employed with metals, is foreseen by Dr. Fraser P. Price, General Electric Research Laboratory, who reported on his work at the recent Diamond Jubilee of the American Chemical Society.

In his paper presented before a symposium on fluorine chemistry, Dr. Price described how plastic crystals may be made to form by proper application of heat, in a manner closely analogous to crystal formation in a metal such as steel. In the plastic as in the metal each crystal forms around a nucleus of some foreign matter or "dirt."

The research was concerned with a plastic bearing the name of "polychlorotrifluoroethylene." As prepared, it is in the form of clear sheets. If heated to more than about 400F, at which it softens and becomes rubbery, and then allowed to cool slowly the sheet becomes cloudy.

Studies of this cloudy plastic by special microscopes, x rays and other methods revealed many tiny circular groups of crystals, each group a hundredth of an inch or less in diameter. The electrical and mechanical properties of the plastic containing crystals are very different from those of the normal form, where there is no regular order in the arrangement of the atoms of which it is made. In a crystalline material they are arranged in a regular lattice. It is said that the crystal formation occurs mainly at temperatures above 350F. The nuclei, around which the crystals form, are provided by the "filler" that is added to the plastic in manufacturing.

He said that similar effects occur with many types of plastics including nylon and polyethylene, which is widely used as a transparent covering. In discussing possible applications of his work, Dr. Price said that choice of the proper heat treatment and filler might afford means of regulating the properties of a plastic.

School-Lighting Booklet Available

Protection of school children's eyes is pointed up by a revised 20-page ABC Plan School Lighting booklet available from the Westinghouse Electric Corporation.

The booklet outlines six basic points that should be considered before buying a lighting system and applies these points to several problems typical to most schools. Complete data and sketches are provided for eight sample lighting layouts, and photographs and descriptions of seven types of luminaires are included.

For a copy of booklet B-4556-A, write to Westinghouse Electric Corporation, Box 2099, Pittsburgh 30, Pennsylvania.

How to Make Homework Lighter

"How to Make Homework Lighter," a new 8-page, two-color booklet for use by electric light and power companies and cooperating dealers in disseminating information on the application of good lighting principles to home study, has been prepared by the Better Light Better Sight Bureau.

Attractively printed, this brochure is a revised and enlarged version of a popular and widely used folder previously published under the same title. The copy is informal and designed to appeal both to parents and to school-age children.

Examples of correct lighting for study are illustrated and described, in contrast with photos and descriptions of incorrect lighting in the same setting. Included also is a description of a "Portable Study Center," which students can build, together with photos and drawings with instructions for its construction. Many of the common faults in the placement of lamps are pointed out, with useful practical suggestions as to how the lighting may be improved without the necessity of extensive room changes.

"How to Make Homework Lighter" may be obtained from the Better Light Better Sight Bureau, 420 Lexington Avenue, New York 17, N. Y. This booklet is priced at $3.50 per 100, in minimum quantities of 100.

Occupational Optometry Section Meets in New York

The newly formed Occupational Optometry Section of the American Academy of Optometry held its first sessions during the annual meeting of the Academy, December 8-11, at the Hotel New Yorker, New York City.

At the first meeting, the objectives of the Occupational Section were stated as the garnering of all useful information which relates to occupational seeing and the proper distribution of this knowledge to the groups interested. Sub-committees were named to carry out this work. They will deal with specific problems such as seeing in industry, on the highway, in schools and in other occupational environments.

At the second session, papers were presented by Dr. Charles Bridgman, Chairman of the Bureau of Industrial Psychology, University of Wisconsin, "Occupational Aspects of Vision from the Industrial Psychological Viewpoint"; Sylvester K. Guth, Head of the Lighting Research Laboratory, General Electric Company, "A Broad Concept of Lighting on the Job"; Gideon Lange, Optometrist, Concord, N. C., "An Industrial Vision Program"; Mr. R. A. Sherman, Director, Department of Occupational Vision, Bausch and Lomb Optical Company, "A History of Industrial Vision"; Commander R. Roswell Sullivan, Head, Optometry Section, Department of the Navy,, "Optometry in the Navy."

The third session was in the form of a trip to the Sperry Gyroscope Company at Lake Success. Here the group of 22 was addressed by Dr. Raymond Murray, Medical Director, Dr. Herman Sager, Director of Eye Service, and Mr. Fred Kiefer, Safety Engineer.

The Committee of the Occupational Vision Section of the Academy is composed of the following:

Chairman, Dr. Richard Feinberg, Northern Illinois College of Optometry, 4170 Drexel Boulevard, Chicago; Dr. C. S. Bridgman, University of Wisconsin, Madison; Dr. L. Wayne Brock, Greenville, S. C.; Mr. Sylvester K. Guth, Nela Park, East Cleveland, Ohio; Dr. Richard M. Hall, Cleveland; Dr. Herman Sager, Lake Success, N. Y.; Mr. R. A. Sherman, Rochester, N. Y.; Dr. Donald A. Springer, Anniston, Ala.; Commander R. Roswell Sullivan, Washington, D. C.; Dr. Lee M. Wheless, High Point, N. C.; Dr. Heary Day, Sr., Raleigh, N. C.; Dr. Gideon Lange, Concord, N. C.

The Committee is interested in working with professional groups having common goals, and requests that all inquiries be addressed to the Chairman.

(*Continued on page 17A*)

2800-square-foot PLEXIGLAS luminous ceiling in Rohm & Haas Company Engineering Building, Bristol, Pa. Corrugated white translucent PLEXIGLAS is mounted wall-to-wall below continuous runs of fluorescent lamps. Upper window glazing is corrugated gray PLEXIGLAS, for prevention of sky glare.

ENVIRONMENTAL LIGHTING . . . With a PLEXIGLAS Luminous Ceiling

For *environmental* room lighting, the whole field of view must be in brightness balance . . . as in this drafting room with its PLEXIGLAS luminous ceiling.

The surface brightnesses of the ceiling, the walls, and the window areas of this room are less than three times as bright as the paper on the drawing boards. Note how these surfaces produce a field of uniform brightness in which there are no eye-fatiguing light-to-dark contrasts.

An average illumination of 118 footcandles is provided through the PLEXIGLAS diffusing panels, without objectionable direct glare from the large-area ceiling surface.

PLEXIGLAS acrylic plastic offers other advantages as a diffusing medium. Because it is rigid, light in weight, and strong, PLEXIGLAS can be handled easily and safely during installation, cleaning, and relamping operations. And because it is highly resistant to breakage and discoloration, it gives long, low-maintenance service.

If *you* have a lighting problem, investigate *environmental* lighting with a PLEXIGLAS luminous ceiling. We'll be glad to send you full technical details about the installation shown above. Write for them.

CHEMICALS FOR INDUSTRY

ROHM & HAAS COMPANY

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Representatives in principal foreign countries

PLEXIGLAS *is a trade-mark, Reg. U. S. Pat. Off. and in principal foreign countries.*

Canadian Distributor: Crystal Glass & Plastics, Ltd., 130 Queen's Quay at Jarvis Street, Toronto, Ontario, Canada.

20 MILES OF FIXTURES.....

in only six months
MORE THAN 2,000*
SCHOOLROOMS
and many well known offices
have been improved by . . .

*Based on shipping records for 6 months

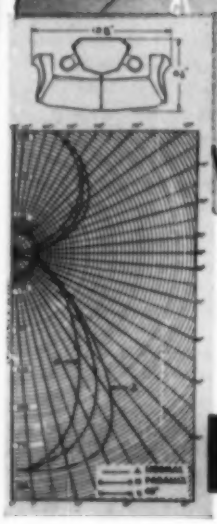
5030 Visualier series available in 4 ft. and 8 ft. units — two lamp rows — fluorescent or slimline — individual mounting or continuous runs. Four lamp matching fixtures also available.

GARCY'S *Visualier*

WHY? Because only Visualier checks "YES" on all these points

- 45° x 45° SHIELDING
- 50-50 LIGHT DISTRIBUTION
- 77% LIGHT UTILIZATION
- Softly illuminated side panels for low surface brightness.
- Far exceeds I.E.S. and A.I.A. school lighting specifications.
- All metal construction — no glass or plastic to break or warp.
- One-piece louver shield — hinged from either side or removable.
- Large louver cells easily cleaned from floor with brush or vacuum.
- Couple perfectly for continuous runs.

Literature and E.T.L. data sent on request.



GARDEN CITY PLATING & MFG. CO.
1760 N. Ashland Ave. · Chicago 22, Ill.

(Continued from page 14A)

IT SEEMS TO ME

Bare Lamp Fixtures in Schools

To the Editor:

There may be some interest to the readers of IE, in a recent exchange of correspondence with a New England architect on the question of the practicality and desirability of using exposed fluorescent lamps for relighting old schools.

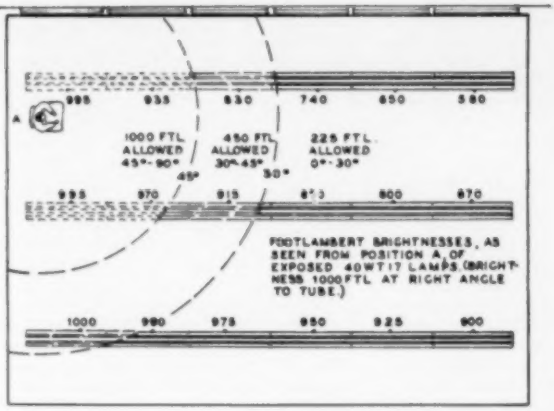
In his request for an opinion on an installation using exposed 40-W T-17 low-brightness lamps, the architect listed the following information in regard to it:

a. Average lumens per square foot on desk tops — 75.
b. Average lumens per square foot over entire room — 70.
c. Maximum brightness of ceiling (directly over fixtures) — 104 footlamberts.
d. Minimum brightness of ceiling (in between rows of fixtures) — 30 footlamberts.
e. Maximum brightness of lamps (at right ang'es to axis of lamp)—960 footlamberts.
f. Center of chalkboard at front of room indicated 42 lumen per square foot and 8 footlamberts. (38 lumen per square foot at bottom of chalkboard)
g. Maximum reading at desk tops (22½" above floor) — 86 lumens per square foot.
h. Minimum reading at desk tops—60 lumens per square foot. (These readings occurred at corner desks.)
i. Center of chalkboard at side of room indicated 6.5 footlamberts, with green wall above giving 42.5 footlamberts.

The reply was:

We believe we can understand why you are interested in this particular form of lighting. Its low cost, and its easier maintenance are outstanding points to be seriously considered. However, we hesitate to acquiesce to the suitability of such bare lamp sources for schoolroom lighting. Historically speaking, the lighting field went through a critical period of many complaints in the early days following the advent of fluorescent lighting. Published articles and heavy correspondence indicated the widespread difficulty and comment. We are enclosing a copy of a typical letter which was compiled to answer the many hundreds of complaints which came to this office. The gist of the whole matter appeared to be the use of unshielded fluorescent lamps. I believe you can see with this background why we are hesitant in agreeing to the use of this improved form of bare lamp installation.

At the time that the 1948 edition of the American Standard Practice for School Lighting A23 was being developed very careful consideration was given to this problem which was fresh in mind. The best available data were brought together and pooled experiences of those skilled in this field brought to bear on the final conclusions. This resulted in the development of Table 4 which is quoted as follows:



Zone (0° is directly beneath luminaire)	Recommended Brightness in Footlamberts*
60° - 90°	225
45° - 60°	450
0° - 45°	1000

*Comparative values in candles per square inch, respectively, .5, 1.0, 2.

These limits as expressed in Table 4 were the recommended objective of the Committee. However, due to the experience factor it was found that some luminaires could be considered acceptable if they had double the brightness of the provisions in the Table when light finishes were used in the lower part of the room. Therefore, a "doubling rule" was provided for these conditions. I do not know in detail how the bare lamp fixtures which you describe meet these provisions of the American Standard Practice for School Lighting.* From your quoted figures they do not meet the Practice when viewed normal to the lamps. From the best available information I have at hand I do not believe they meet the provisions when viewed lengthwise. Therefore, in view of the serious situation in respect to the early use of fluorescent lighting and the best available information and experience as recorded in the American Standard Practice I do not see how our Society could express approval of a type of lighting which would be contradictory to our recommendations.

We make the above statements in a spirit of utmost kindliness toward those who are fully persuaded in their own minds that this is an acceptable and desirable form of lighting. It is, no doubt, their belief that the disadvantages are outweighed by the advantages and that the brightness of the lamps may casually appear acceptable, especially under bright daylighting conditions where the higher level of illumination tends to reduce the contrast of the brightness of the lamps and when only one or two rows may be on at a time. However, for continued hours of study for dark winter days and for possible nighttime use we would kindly express a word of caution.—C. L. Crouch, *Technical Director, Illuminating Engineering Society, New York, N. Y.*

✱ THE ASA AMERICAN STANDARD PRACTICE FOR SCHOOL LIGHTING PERMITS DOUBLING THE ABOVE VALUES IF THE BRIGHT AREAS OF THE LUMINAIRE ARE SMALL AND THE ROOM IS FINISHED IN ACCORDANCE WITH RECOMMENDED REFLECTANCES.

*Since dispatching the above letter a sketch has come in from the School Lighting Committee channels which illustrates more precisely the problem of brightness relationships involved.

ABOUT PEOPLE

Certificate to Fellow grade in I.E.S. and the white lapel emblem signifying this highest grade of membership were presented to **Dr. Rolland M. Zabel,** of Westinghouse Electric Corp., Bloomfield, N. J., at the President's Night meeting of the New York Section, December 12. **Ernest A. Salter,** Section Chairman, made the presentation.

A. H. Taylor, physicist retired from the General Electric Research Laboratories, Nela Park, and **L. C. Kent,** recently retired Director of the Nela Park Institute, were elected to Member Emeritus of I.E.S. by action of Council on December 13.

(Continued on page 18A)

(Continued from page 17A)

G. H. Stickney, "senior statesman" of the Society, was a visitor to the meeting of Council of I.E.S. on December 13. Mr. Stickney, beloved "Uncle George" to hundreds of I.E.S. members, is still, after more than 45 years, active in Society affairs.

Gilbert K. Hardacre, manager of commercial sales, Public Service Co. of Northern Illinois, has been re-elected president of the Chicago Lighting Institute. **A. G. Nelson**, Lamp Division of Westinghouse Electric Corp., was elected vice president; and **E. J. Doyle, Jr.**, Commonwealth Edison Co., is secretary-treasurer.

John G. Waddell, managing director of the Electric Institute of Boston, Inc., was elected president of the International Association of Electrical Leagues at its sixteenth annual conference in New Orleans.

The 1951 Edison Medal for "distinguished contributions in the field of power system engineering" has been awarded to **Dr. Charles F. Wagner**, Westinghouse Electric Corp. The medal will be presented during the Winter General Meeting of the American Institute of Electrical Engineers, in New York January 21-26.

E. L. Dodington, formerly professor at the University of Toronto, has joined Sterling Electrical Company, St. Catherines, Ontario as vice-president and general manager.

The Portable Lamp and Shade Manufacturers Association has announced the new officers. Chairman of the Board is **George H. Weiner**, Deena Products Co.; Honorary Chairman, **A. L. Sandel**, Sandel Mfg. Co.; President, **Ben Glassman**, Rembrandt Lamp Corp.; Treasurer, **R. W. Jewell**, Art Lamp Co.; and Secretary, **Richard Weiss**, Colonial Premier Co.

Lawrence P. Pleasants has been appointed merchandising manager, Lamps, of the Lighting Division of Sylvania Electric Products Inc., and will have headquarters in Salem, Mass.

NEW MEMBERS

At the meeting of the Council Executive Committee held in New York City on December 13, 1951, the following were elected to membership:

ARIZONA CHAPTER

Member:
Hamilton, Marriel, New State Electric Co., Phoenix, Ariz.
Associate Members:
Kimsey, W. L., Central Ariz. Light & Power Co., Phoenix, Ariz.
Sage, W. L., Central Ariz. Light & Power Co., Phoenix, Ariz.

BALTIMORE CHAPTER

Associate Member:
Schmidt, D. G., Jr., Sylvania Electric Products, Inc., Alexandria, Va.

BRITISH COLUMBIA SECTION

Associate Members:
McGregor, Miss D., B. C. Electric Co. Ltd., Vancouver, B. C.
Therriault, M., Van Horne Electric Supply, Vancouver, B. C.

CAPITAL SECTION

Associate Member:
Bailey, E. F., Potomac Electric Power Co., Washington, D. C.

CENTRAL NEW YORK SECTION

Associate Members:
Freije, J. B., Freije Electrical Supply Co. Inc., Binghamton, N. Y.
Kuschwa, R. L., Sylvania Electric Products Inc., Buffalo, N. Y.
Student Member:
Doggett, F. F., Cornell University, Ithaca, N. Y.

CHICAGO SECTION

Associate Members:
Altman, N. P., Holabird & Root & Burgee, Chicago, Ill.
Chappell, E. R., Benjamin Electric Mfg. Co., Des Plaines, Ill.
Ford, J. R., Special Products Div., Chicago 41, Ill.
Kempner, J. H., Southern Plastics Co., Chicago 1, Ill.
Wera, L. J., Jr., Benjamin Electric Mfg. Co., Des Plaines, Ill.
Student Members:
Calandrino, P. J., University of Illinois, Urbana, Ill.
Delcour, L. R., University of Illinois, Urbana, Ill.
Fairbanks, R. E., University of Illinois, Urbana, Ill.
Kaswan, Jerry, University of Illinois, Urbana, Ill.
King, Benny, University of Illinois, Urbana, Ill.
Schneider, D. N., University of Illinois, Urbana, Ill.
Williams, H. G., University of Illinois, Urbana, Ill.

CLEVELAND SECTION

Members Emeritus:
Kent, L. C., 19406 Van Aken Blvd., Shaker Heights, Ohio.
Taylor, A. H., 16304 Helmsdale Rd., East Cleveland, Ohio.
Associate Members:
George, A. B., Wilbur Watson Associates, Cleveland 3, Ohio.
Lucas, D. J., General Electric Supply Corp., Cleveland, Ohio.

EASTERN PENNSYLVANIA SECTION

Member:
Troy, C. T., Northern Penna. Power Co., Towanda, Pa.
Associate Members:
Molb, E. H., 40 N. 9th St., Allentown, Pa.
Mandolos, Gus, Bright Sign Service, Reading, Pa.
Perlmutter, I. M., 736 Turner St., Allentown, Pa.
Reagan, P. J., Schaedler Bros., Harrisburg, Pa.

FLORIDA CHAPTER

Associate Members:
Dunphy, H. E., Florida Power Corp., St. Petersburg, Fla.
Lockaby, J. D., Tampa Electric Co., Tampa, Fla.

HAMILTON, ONTARIO CHAPTER

Associate Member:
Cossins, W. F., Cossins Electric Ltd., Hamilton, Ont.

INDIANA CHAPTER

Associate Members:
Butler, R. T., Westinghouse Lamp Corp., Indianapolis, Ind.
Coffin, A. S., Jr., Public Service Co. of Indiana, Inc., Wabash, Ind.
Parker, W. H., Public Service Co. of Indiana, Inc., Lafayette, Ind.

IOWA SECTION

Member:
Reece, W. T., Jr., General Electric Co., Des Moines, Ia.
Associate Members:
Kendrick, R. H., Electrical Engineering & Equip. Co., Des Moines, Ia.
Lee, C. O., Bert J. Clark Co., Kansas City, Mo.
Prosch, C. E., B. E. Landes, Des Moines, Ia.

MARITIME CHAPTER

Associate Member:
Wilkinson, K., Northern Electric Co., Ltd., Halifax, N. S.

MICHIGAN SECTION

Associate Member:
Dombrowski, R. L., Smith, Hinchman & Grylls, Inc., Detroit, Mich.

MILWAUKEE SECTION

Associate Members:
Boemster, Henry, Boemster Electric Co., Green Bay, Wis.
Somerville, J. E., 403 W. Walnut St., Green Bay, Wis.

MISSISSIPPI CHAPTER

Associate Member:
Briggs, R. E., 303 Stillwood Dr., Jackson, Miss.

MONTREAL SECTION

Associate Members:
Blouin, Maurice, Blouin & Lafrancois, Trois Rivieres, Que.
Trepanier, Jacque, Standard Cold Cathode Co., Montreal, Que.

NEW ENGLAND SECTION

Associate Members:
Cherry, C. R., Champion Lamp Works, Lynn, Mass.
Fulle, A. W., Sylvania Electric Products Inc., Boston, Mass.
Mikita, T. E., Sylvania Electric Products Inc., Salem, Mass.
Rosequist, D. B., Wheeler Reflector Co., South Hanson, Mass.
Thorpe, R. L., Alonzo J. Harriman, Inc., Auburn, Maine.

NEW ORLEANS SECTION

Associate Members:
Moragas, John, Interstate Electric Co., New Orleans, La.
Vogt, I. O., de Laureal & Moses, New Orleans, La.

NEW YORK SECTION

Fellow:
R. M. Zabel, Westinghouse Electric Corp., Bloomfield, N. J.
Member:
Lemmon, M. P., Arabian American Oil Co., New York, N. Y.
Associate Members:
Levine, J. L., Century Lighting Co., Inc., New York, N. Y.
Wadams, B. N., 23 Sherman Court, Bloomfield, N. J.
Student Member:
Beesley, E. M., Walter Kidde Constructors, New York, N. Y.

NORTHERN CALIFORNIA SECTION

Associate Members:
Baker, G. E., Haluk Lighting & Mfg. Co., San Francisco, Calif.
Barber, D. H., Standard Oil Co. of Calif., San Francisco, Calif.
Bell, Dewey, Electrical Products Corp., San Francisco, Calif.
Broida, T. R., U. S. Naval Radiological Defense Lab., San Francisco, Calif.
Crandall, R. H., Westinghouse Electric Supply Co., Oakland, Calif.
Rifkin, David, Marvin Mfg. Co., San Francisco, Calif.
Student Member:
McCollum, M. L., University of California, Berkeley, Calif.

(Continued on page 20A)

The costliest place to catch mistakes is here→

Best-lighted area in most plants today is the inspection table. But good inspection lighting can only help catch errors *after* they occur—and time and materials have already been wasted.

The cheapest place is here→

By giving their production workers as good light as they give inspectors, your customers prevent mistakes from happening. There are fewer errors, less fatigue, fewer accidents.

Photos courtesy Metals & Controls Corp., Attleboro, Mass.

THE BEST WAY IS WITH "5-WAY IMPROVED" G-E FLUORESCENT LAMPS IN LIGHTING FIXTURES!

AS a result of recent improvements made by General Electric lamp research scientists, you now can offer your customers:

(1) Increased efficiency (improved phosphor)

(2) Better uniformity (improved processes)

(3) Less end blackening (purer materials, more accurate controls)

(4) Longer life (new materials and methods)

(5) Better color rendition (new Deluxe White lamps show colors as they really are)

Workers see better, work better under cool fluorescent light with less glare, fewer shadows. Newest form of fluorescent is G-E slimline—up to 8′ long, single pin base, instant starting.

FREE BOOKLET! How to light up for better production. For your copy of "Planned Lighting for Industry," write General Electric, Department 166-IE-1, Nela Park, Cleveland 12, Ohio.

You can put your confidence in

GENERAL ELECTRIC

KEEP LIGHTING EFFICIENCY UP!

with New
JEFFERSON TRANSFORMERS
For Mercury Vapor Lamps

• Correctly and specifically designed for modern lighting service—Jefferson Transformers provide the proper starting and safe operating voltage and current for long-life, lowest cost lamp operation. The Jefferson accuracy of design controls the voltage and current to uniform predetermined specifications so vital to satisfactory lamp performance.

Designed by transformer specialist engineers and by a company that has devoted over 35 years to this one type of product — these transformers keep your mercury lamp lighting efficiency up and maintenance down. They are designed to meet the specifications of leading lamp manufacturers.

Both the single and two-lamp Transformers have *three* primary taps so a close match with the voltage of circuit to which lamps are connected can be selected for best results.

Wiring compartments of Indoor Types are roomy, ½-in. and ¾-in. knockouts provided and fittings at top and bottom for conduit and for suspension installation.

Our new Bulletin 521-5 includes complete data on indoor and outdoor transformers. Copy will be mailed on request.

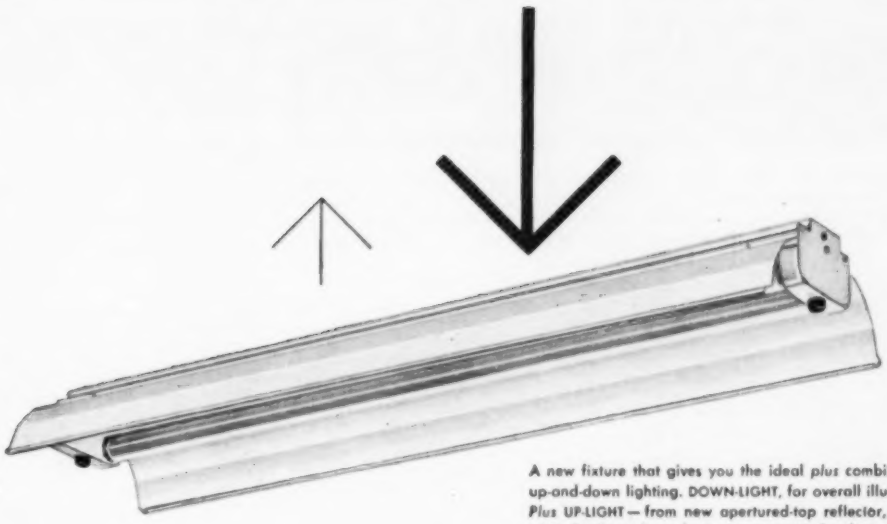
Jefferson Transformer for wall, post, ceiling, pendant or messenger wire mounting.

Two-lamp Transformers serve two lamps, provide many savings in first cost, wiring and installation.

Weatherproof outdoor type for lamps used in lighting plant areas, boundaries, building fronts, etc., suitable for attaching to wall or post, or installed on pole top by means of an Adapter.

JEFFERSON ELECTRIC COMPANY • Bellwood, Illinois

IN CANADA: Canadian Jefferson Electric Co., Ltd., 384 Pape Ave., Toronto, Ont.



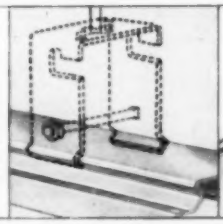
A new fixture that gives you the ideal *plus* combination of up-and-down lighting. DOWN-LIGHT, for overall illumination. *Plus* UP-LIGHT — from new apertured-top reflector, new all-white finish inside and out — to minimize brightness contrast (and give sufficient light for overhead maintenance). Result — a new high standard of illumination that enables workers to see easily and work better.

A more compact fixture, too, made possible by the use of the new G.E. small cross-section ballast. Long life assured by rigid adherence to the Miller 8-Point QUALITY standard. Engineered for easy installation and maintenance. Carries RLM label. Can be mounted individually or in continuous rows. Delivery — excellent.

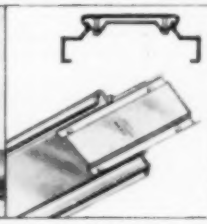
a new plus in industrial lighting

miller *50 FOOT CANDLER JR.*

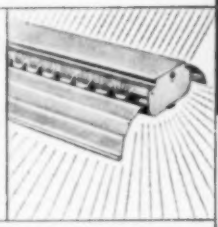
New all-white finish — baked enamel — RLM porcelain enamel.



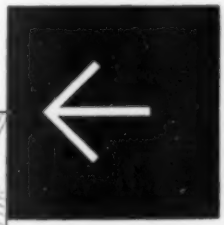
Flanged-top wireway channel permits clamp hanger mounting anywhere along entire length — simplifies installation.



New pressure-type connector for joining luminaries for continuous rows. No holes to drill.



New apertured-top reflectors, minimize brightness contrast — give sufficient up-light for overhead maintenance.



New small cross-section G.E. #89G343 ballast — streamlined wireway.

This, the husky son of our famous 50 Foot Candler, is the newest of a complete line of Fluorescent, Filament and Mercury fixtures for a wide range of industrial and commercial lighting requirements. Miller field engineers and distributors are conveniently located for nation-wide service.

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NEW EQUIPMENT DATA

AVAILABLE WITH COUPON

New manufacturers' catalogs and bulletins listed below are available free to readers of ILLUMINATING ENGINEERING by mailing the coupon. Circle the numbers of those items which you want, drop in envelope or fasten securely to back of penny postcard addressed to Publications Office.

1 Sec. 2G bulletin describes the "Marketer" fluorescent luminaire for store lighting; gives dimensional and installata data as well as specifications. Miller Co., Meriden, Conn.

2 Newly designed circuit breaker for use in panelboards handling lighting and appliance circuits and interchangeable with other conventional breakers is described in this company's Bulletin 3101, giving complete information and specifications. Heinemann Electric Co., Trenton, N. J.

3 School lighting booklet pictures various new lighting jobs in schools across the country; another booklet shows how Denver public schools transformed lighting. Day-Brite Lighting Inc., St. Louis, Mo.

4 Novel 50-page catalog in full color shows company's complete line of residential fixtures; includes revolving disc in cover to show various room layouts; illustrated index of all fixtures shown in the catalog. Moe Light Inc., Fort Atkinson, Wis.

5 78-page construction Catalog 700, fully illustrated, is simple, easy-to-use manual on how to frame, hang, mount and support many mechanical and electrical equipments with company's all-metal framing. Unistrut Products Co., Chicago, Ill.

6 Catalog No. 48 "Lighting for Production" in 16 pages describes company's line of "Wyte-Liner" fluorescent luminaires for industrial lighting. Brochure gives construction features, specifications, and stresses quality of light in industry. Edwin F. Guth Co., St. Louis, Mo.

7 Catalog No. 80 consists of 20 pages devoted to company's line of aluminum poles for street and highway lighting; complete with engineering tables covering fluted and plain round design, gives bracket styles and mounting heights from 19 to 37 feet. Union Metal Mfg. Co., Canton, Ohio.

8 Bulletin C5-1 gives construction and specification details on new fluorescent luminaire "Norwin" suited to school and office applications; may be installed in four different ways. Pittsburgh Reflector Co., Pittsburgh, Pa.

9 Catalog 19-470 for product designers covers wires, cables, and cords manufactured by company; gives complete specification data, construction and applications for all types of wire for many electrical equipments. General Electric Co., Bridgeport, Conn.

10 Four-page 5458-LB bulletin gives detailed description of new Gill luminaire designed particularly for school installations where ease of maintenance is important factor. Data include complete ETL engineering tests. Gill Glass & Fixture Co., Philadelphia, Pa.

11 Catalog pages contain information on ultraviolet germicidal equipment, giving complete specifications as to effectiveness and radiation of units. D. William Fuller Co., Chicago, Ill.

12 New "Datalog," 64 pages of information on all Holophane products, gives cross-sectional drawings, distribution curves on 270 luminaires, with special emphasis on description, performance, application and installation. Holophane Co., New York, N. Y.

13 "QuelArc" bulletin describes in detail and illustrates safety and durability construction features of company's heavy-duty connectors; includes tables of sizes and styles; gives typical circuit diagrams. Pyle-National Co., Chicago, Ill.

14 Booklet B-4791 provides complete plans for outdoor industrial lighting in 24 pages, "Light for Plant Safety and Security"; stresses protective lighting for various industry boundaries such as fences, etc. Westinghouse Electric Corp., Pittsburgh, Pa.

15 Section 9 catalog gives 50 pages of information on company's line of street lighting luminaires including photometric data, construction and installation details on luminaires and accessories, complete with drawings. Joslyn Mfg. & Supply Co., Chicago, Ill.

16 Bulletin 551-11 covers company's new series sequence 430 ma ballast for series operation of two 96T12 fluorescent lamps. Includes weight, dimensions and wiring diagram; meets proposed A.S.A. test specifications C82.1. Jefferson Electric Co., Bellwood, Ill.

17 Catalog 433 describes in detail complete line of commercial fluorescent lighting units in 29-page, two-color illustrated booklet. Catalog gives complete specifications, performance and photometric data; describes accessories. Mitchell Mfg. Co., Chicago, Ill.

18 Mercury vapor lamps, Type H, are illustrated in new bulletin which gives specifications, order numbers, etc. on 18 different types of lamps and transformer. Hanovia Chemical & Mfg. Co., Newark, N. J.

19 72-page catalog shows company's complete line of incandescent and fluorescent fixtures for wide variety of application; includes specifications, installation and construction details, photometric data. Globe Lighting Products Inc., New York, N. Y.

20 "Analysis of Plug-In Strip vs. Duplex Outlet Wiring" discusses the two types of wiring for home outlets; tells advantages claimed for plug-in. National Electric Products Corp., Pittsburgh, Pa.

21 20-page school lighting booklet B-4556-A outlines six basic points to be considered in buying a lighting system; provides data and sketches for sample lighting layouts; gives photographs and descriptions of luminaires. Westinghouse Electric Corp., Pittsburgh, Pa.

22 GEA-5672, 4-page, two-color brochure describes how company's ballasts are "sound-rated," classified according to amount of natural hum they emit. Folder explains how ratings can be used, with a typical application; lists catalog number according to ratings. General Electric Co., Schenectady, N. Y.

23 Bulletin 40 describes heavy-duty lamps for industrial applications; R-type floodlights, R-40 Infra-red and spatter-proof lamps; as well as company's standard lamps. Folder gives specifications and special features. Radiant Lamp Corp., Newark, N. J.

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THE STAR has a translucent Plaskon reflector which completely shields the fluorescent lamps. When the lamps are lit the reflector and the ceiling above it are of approximately equal brightness. Thus glare, both direct and reflected, is reduced to a minimum.

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On this page are shown several of the relighted rooms. Walls were painted in soft pastel shades with good reflectances. For the first six grades, new movable blond furniture was purchased. Older furniture was sanded and brought up to no-glare, high reflectance standards. Floors were refinished in light colors or covered with light-colored tile.

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Ceiling — 12'
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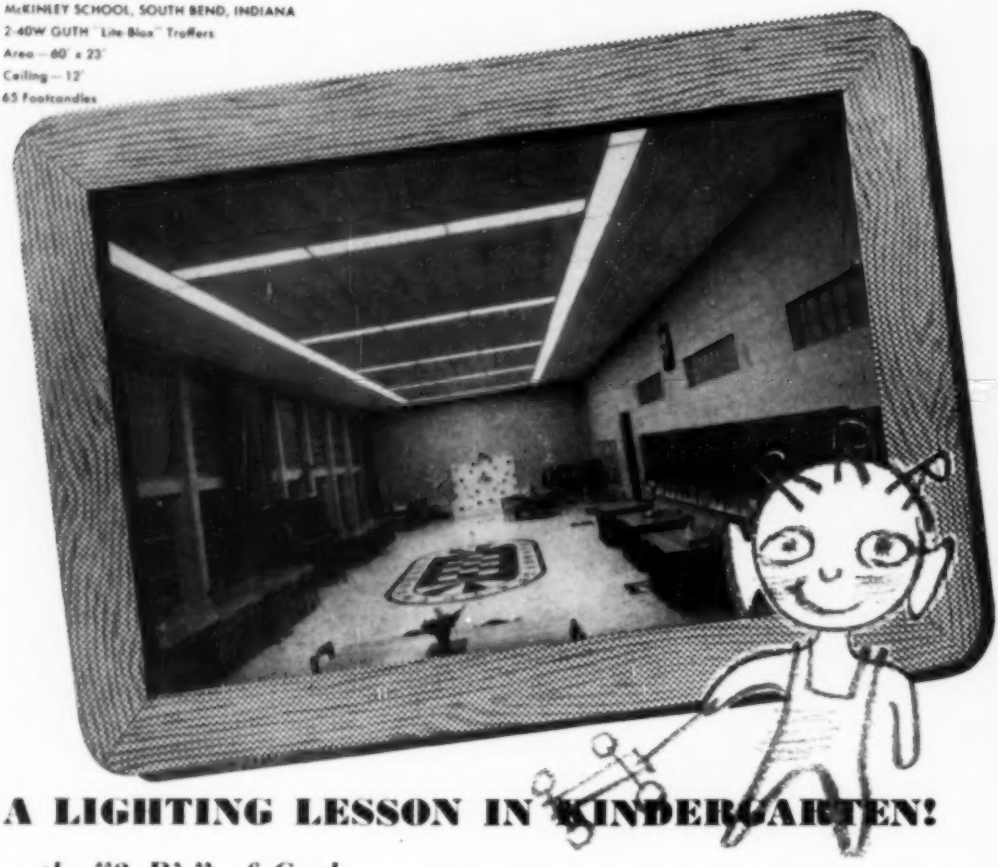

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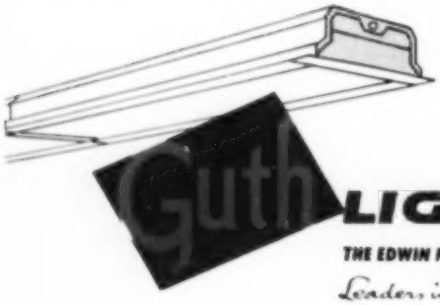

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Today, in defense industries, as well as in schools, factories, stores and homes, up-to-date lighting is vitally important. The †PC *Vision-Lighting Plan* complements your electric lighting plan by making the most of daylight. And, as indicated in the two typical installations here, it is a practical plan for *all* sections of the country.

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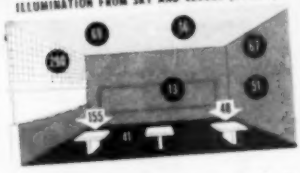
TYPICAL DAYLIGHTING PERFORMANCE IN ACTUAL INSTALLATIONS

The following "on-the-job" readings from widely-separated communities, are typical of PC Vision-Lighting Plan installations. Continual checks are made of product performance in the field to supplement tests conducted on PC Functional Glass Blocks at the Pittsburgh Corning Daylighting Research Center, Port Allegany, Pa., and independent research laboratories.

ILLUMINATION FROM SKY AND CLOUDS (NO SUN)



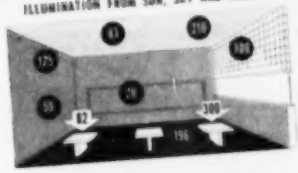
Carthage Junior-Senior High School, Carthage, Texas
Architect: Preston M. Geren, Fort Worth, Texas

Classrooms: 22' x 29' 8", with 11'10½" ceiling. 150 sq. ft. glass block panel (28.4% of floor area); 73 sq. ft. vision sash (13.1% of floor area).

North room (see sketch): PC Prism A Glass Blocks used. Illumination of panels: 1580 footcandles. Canopy shaded vision strip.

Surface reflectances: Ceiling, 74%; walls, 70%; chalkboard, 18%; backboard, 82%; floor, 30%.

ILLUMINATION FROM SUN, SKY AND CLOUDS



Willamette School, Willamette, Oregon
Architect: Donald W. Edmundson, Portland, Oregon
Associate Architect: Neil R. Kochendoerfer, Portland, Oregon

Classrooms: 25' x 49', with 12'2" ceiling. 192 sq. ft. glass block panel (19.2% of floor area); 86 sq. ft. vision sash (8.6% of floor area).

Southeast room (see sketch): PC Soft-Lite B-55 Glass Blocks used.

Illumination of Panels: 5300 footcandles. Sun altitude, 25° to 56°; sun azimuth, minus 62° to minus 54°. Canopy shaded vision strip.

Surface reflectances: Ceiling, 75%; walls — upper 70%, lower, 50%; chalkboard, 20%; tackboard, 20%; floor, 40%; desk tops, 43-50%.

● = Average brightness in footlamberts
⇩ = Average illumination in footcandles

† The PC Vision-Lighting Plan is a construction for daylight openings consisting of orientation-keyed areas of PC Functional Glass Blocks (selected for sun or non-sun exposure) used with vision-ventilation areas as required.

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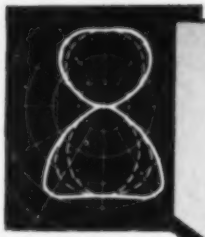

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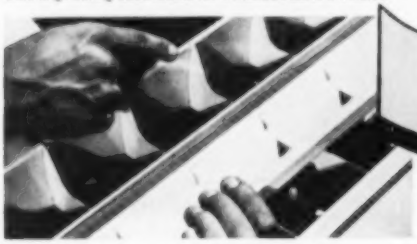

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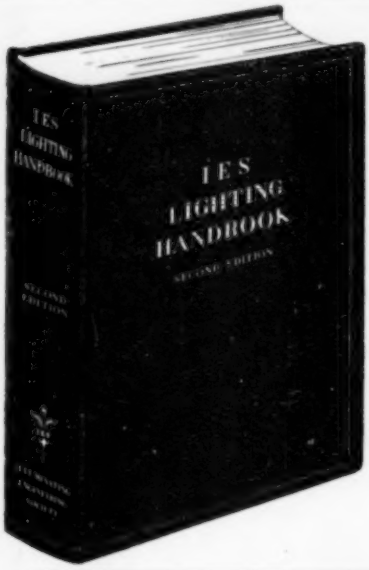

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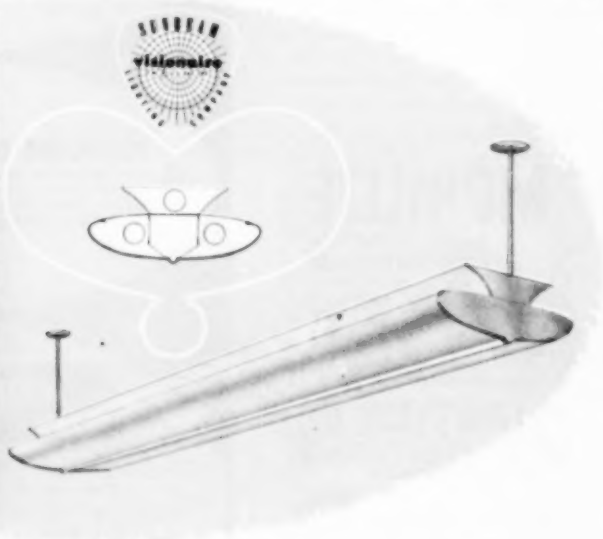

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(Continued from page 18A)

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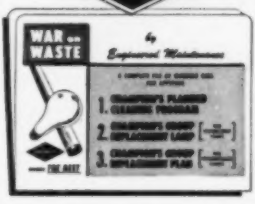

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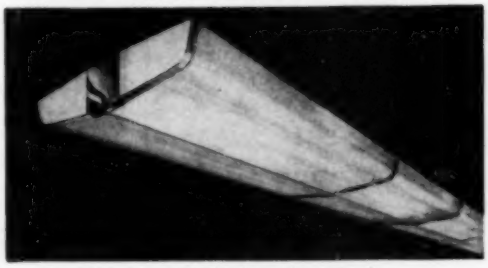

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Litecontrol Corp.	2A
McGraw-Hill Book Co.	30A
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Northern Light Co.	30A
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Rohm & Haas Co.	15A
Sola Electric Co.	32A
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Westinghouse Electric Corp., Lighting	1A

It's no circus

SERVICING YOUR LIGHTS!

GIRAFFE: I'll report this to the S.P.C.A.! My contract says I'm an entertainer, not an extension ladder!

MAINTENANCE MAN: Now don't get excited! You can go back to the circus after I clean these lights.

Well why the $#@%*¢ don't you install THOMPSON HANGERS? Then you could clean these lights at floor level whenever necessary.

Thompson Hangers? Whadda they do?

They lower overhead lights to floor level for servicing. What's more, they completely eliminate all climbing and electrical hazards and cut maintenance costs to a minimum!

S-a-a-a-a-y, that sounds terrific! Are they complicated . . . hard to operate?

The THOMPSON HANGER is simplicity itself! All up-and-down movement is controlled by a chain or cable that's part of the installation, and the hanger automatically repositions itself when raised. The live electrical contacts stay at the top. It's safe and foolproof!

Where can we get more details on these Thompson Hangers?

Write to The Thompson Electric Co. and ask for CATALOG No. 50. It will give you the complete story. Now slide down, chum, and turn me loose!

In traveling with The Big Top, the giraffe has seen many THOMPSON HANGER installations, and he has learned that in each (1) maintenance costs are down to absolute minimum, (2) lighting service men have top safety records and (3) all lights are operating at peak efficiency to facilitate round-the-clock production operations.

Write today for your copy of CATALOG No. 50. There's no obligation.

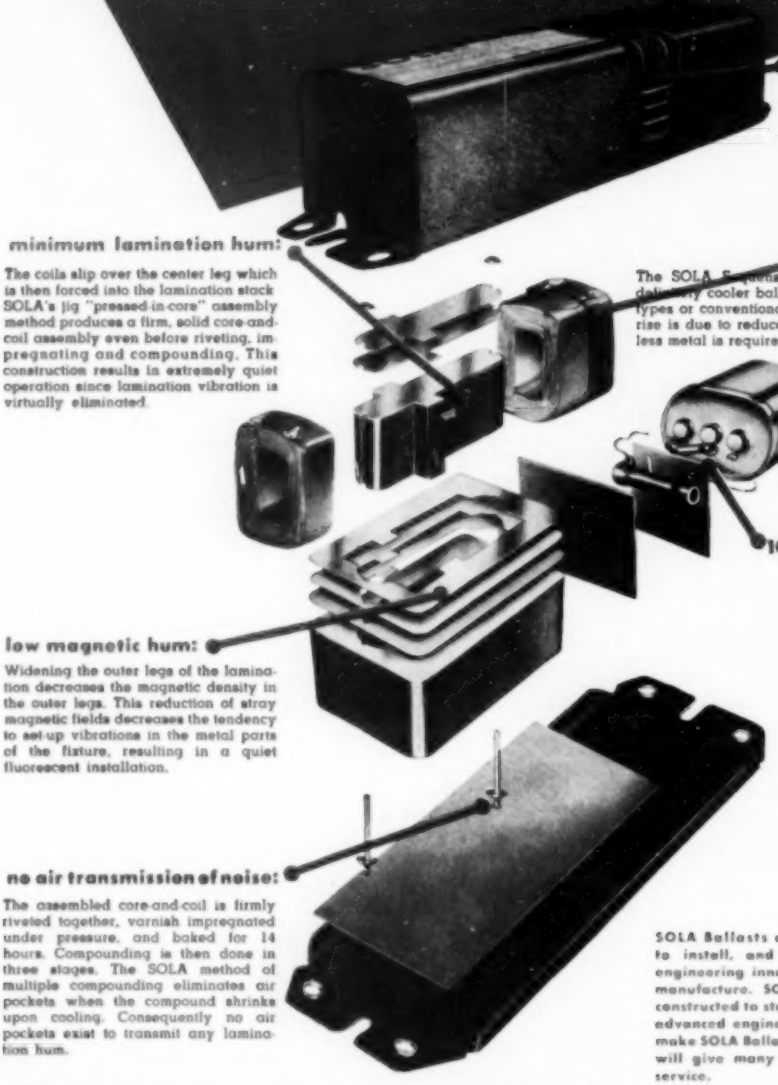
CATALOG No. 50 describes THOMPSON HANGERS and accessory items in detail

THE THOMPSON ELECTRIC CO.

1116 Power Avenue • Cleveland 14, Ohio

the inside story....

OF THE COOLEST, QUIETEST, LONGEST LASTING BALLAST MADE



capacitor protection:

SOLA ballasts are unusually cool in operation; however, the capacitor receives additional protection from any core-and-coil heat because of SOLA's patented ventilated compartment.

minimum lamination hum:

The coils slip over the center leg which is then forced into the lamination stack. SOLA's jig "pressed-in-core" assembly method produces a firm, solid core-and-coil assembly even before riveting, impregnating and compounding. This construction results in extremely quiet operation since lamination vibration is virtually eliminated.

cooler operation:

The SOLA Sequenstart® Ballast design results in definitely cooler ballasts than other series-sequence types or conventional lag-lead ballasts. Lower heat rise is due to reduced copper and iron losses since less metal is required and less energy is dissipated.

100% individual check:

Each capacitor used in a SOLA ballast is checked for electrical characteristics and leakage after a baking cycle.

low magnetic hum:

Widening the outer legs of the lamination decreases the magnetic density in the outer legs. This reduction of stray magnetic fields decreases the tendency to set-up vibrations in the metal parts of the fixture, resulting in a quiet fluorescent installation.

Made under one or more of the following patents: 2,143,745; 2,212,198; 2,346,621; 2,552,111; 2,489,245; and patents pending.

no air transmission of noise:

The assembled core-and-coil is firmly riveted together, varnish impregnated under pressure, and baked for 14 hours. Compounding is then done in three stages. The SOLA method of multiple compounding eliminates air pockets when the compound shrinks upon cooling. Consequently no air pockets exist to transmit any lamination hum.

SOLA Ballasts are constructed to last . . . to install, and then forget. Typical SOLA engineering innovations are evident in their manufacture. SOLA Fluorescent Ballasts are constructed to standards compatible with their advanced engineering design. Together, they make SOLA Ballasts outstanding. SOLA Ballasts will give many years of quiet, dependable service.

Are you on our mailing list? If you would like to receive SOLA literature on lighting transformers, please write to us.

SOLA Sequenstart® BALLASTS

Transformers for: Constant Voltage • Fluorescent Lighting • Cold Cathode Lighting • Airport Lighting • Series Lighting • Luminous Tube Signs Oil Burner Ignition • X-Ray • Power • Controls • Signal Systems • etc. • SOLA ELECTRIC CO., 4633 W. 16th Street, Chicago 50, Illinois

the Role of *Certified Ballasts*

CERTIFIED E·T·L HIGH PF

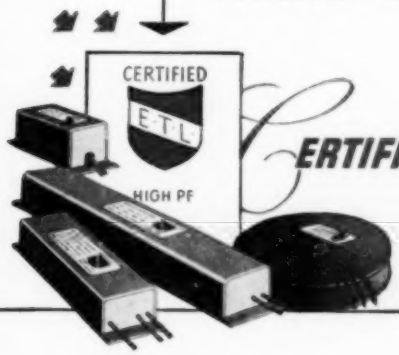
in our National Defense

The making of fluorescent ballasts uses critical materials required in our national defense program.

The Lighting Industry can best conserve available materials by using them most efficiently. To assure *long, trouble-free ballast operation, full lamp life, rated light output and satisfactory fluorescent performance,* insist on CERTIFIED BALLASTS in all fixtures.

CERTIFIED BALLASTS are tested by Electrical Testing Laboratories, Inc., which certifies they meet the precise specifications that assure efficient operation.

TO BE SURE . . . look for the CERTIFIED shield on the ballast.



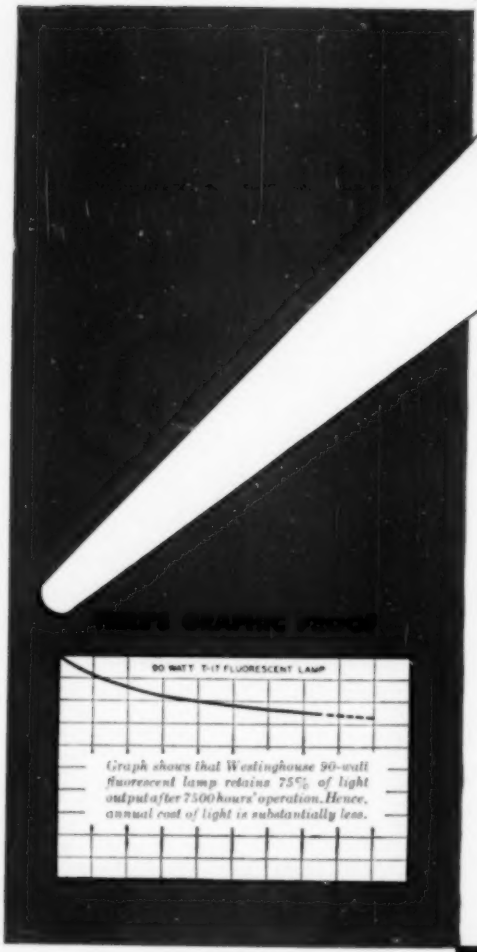
Participation in the CERTIFIED BALLAST program is open to any manufacturer who complies with the requirements of CERTIFIED BALLAST MANUFACTURERS.

CERTIFIED BALLAST MANUFACTURERS

Makers of Certified Ballasts for Fluorescent Lighting

2116 KEITH BLDG., CLEVELAND 15, OHIO

NOW—LIGHT OUTPUT OF WESTINGHOUSE 90-WATT FLUORESCENT LAMP TOPS ALL OTHERS IN ITS CLASS


90 WATT T-17 FLUORESCENT LAMP
Graph shows that Westinghouse 90-watt fluorescent lamp retains 75% of light output after 7500 hours' operation. Hence, annual cost of light is substantially less.

New Improvements Boost Light Output Throughout 7500 Hours Of Operation

The improved *light maintenance* of this exclusive Westinghouse Krypton-Argon 90-watt T-17 fluorescent lamp means that even after 7500 hours of operation it will continue to produce the highest lumen output of any lamp in its class. This gain in light efficiency makes the lamp still more economical for industrial and commercial use.

The improved Westinghouse lamp provides a higher average foot-candle level, and reduces the annual cost of light. It makes a group lamp replacement program more practical and economical. What's more, the Westinghouse 90-watt lamp is designed to operate in any standard 85- or 100-watt T-17 lighting equipment.

For more detailed information on how this new lamp can fit into your present or planned lighting installations, write to Lamp Division, Westinghouse Electric Corporation, Bloomfield, N. J.

YOU CAN BE SURE...IF IT'S **Westinghouse**